

SECTION

System Sizing

CHAPTER 18 Sizing Drainage, Waste,
and Vent Systems

CHAPTER 19 Natural Gas Piping, Water Piping,
and Water Heaters

CHAPTER 18

Sizing Drainage, Waste, and Vent Systems

OBJECTIVES

After completing this chapter, the student should be able to:

- Understand the sizing methods of various segments of a DWV system.
- Interpret codebook sizing tables.
- Understand sizing approaches on a job site.
- Recognize that some minimum pipe-size codes override sizing tables.

GLOSSARY

Arbitrarily chosen: method used to assign a value for drainage fixture units indicating that the theoretic values are adjusted for practical use

Continuous flow: water flow into a drainage system that is introduced either automatically or constantly, such as from a piece of equipment

Drainage fixture unit (dfu): a factor used to size pipe; equals the flow measured in gallons per minute or liters per second into a drainage system from a plumbing fixture

Indirect waste: a pipe that discharges liquid from equipment into a drainage system and terminates with an air gap above a floor drain or fixture

Semicontinuous flow: water flow into a drainage system that is introduced automatically, or that produces more than intermittent and less than continuous flow, such as from a piece of equipment

AN OVERVIEW OF DRAINAGE SYSTEM SIZING

This chapter will explain some methods for sizing a drainage, waste, and vent (DWV) system. Plumbers consider many factors when choosing pipe sizes at a job site; blueprint specifications, applicable codes, and company preference can all affect the sizes that are installed. The blueprint shows the pipe route and specifies minimum pipe sizes. Although a construction company can often increase the pipe sizes, it cannot install smaller pipe sizes than codes allow.

All plumbing codes relating to drains and vents state that no piping in a DWV system shall be smaller than 1 1/4". (This important regulation will remain relevant throughout this chapter.) Indirect drains from equipment are typically not considered drainage pipes under DWV codes, but are regulated differently with **indirect waste** codes.

Plumbers should be aware that pipe sizes installed on a job site are not always the minimum sizes listed in codebooks. For example, codebooks allow lavatory sinks to be served by a 1 1/4" drain or vent, but many companies install 1 1/2" pipe because of availability of materials or costs. A codebook might list 2 1/2" as a DWV pipe size, but most DWV pipe and fitting manufacturers do not offer this size as an option.

TIP When taking a plumbing licensing exam, the answers to questions are based on state and/or local code allowances and not material availability. Many exams may also include plumbing practices of the local area.

One of the most difficult aspects of sizing a DWV system is knowing when various overriding codes will come into play. You can review the various segments of a DWV system discussed in this chapter by returning to Section 5 of this book, "Drainage, Waste, and Vent Systems."

DRAINAGE FIXTURE UNIT

Commonly used plumbing fixtures are assigned a **drainage fixture unit (dfu)** value based on their impact on a DWV system. The International Plumbing Code (IPC) defines a drainage fixture unit as:

A measure of probable discharge into a drainage system by various types of plumbing fixtures. The drainage fixture unit value for a particular fixture depends on its volume rate of drainage discharge, on the time duration of a single drainage operation and on the average time between successive operations. (International Plumbing Code, Chapter 2, "Definitions")

It is important to note that the IPC definition uses the phrase "probable discharge." The dfu values of the fixtures listed in any codebook are **arbitrarily chosen** and are adjusted to a more practical whole value based on the theoretical flow rate of specific fixtures. It is more practical to calculate whole values of probable discharge from a fixture than to calculate specific flow discharge when sizing a DWV system. The IPC definition indicates four factors that determine the dfus for particular fixtures or for a DWV system as a whole: (1) the specific fixture type, (2) how many gallons or liters a fixture discharges into a drain, (3) how fast that volume of water enters the drain, and (4) how often the fixture discharges into the drain.

Using DFU Values to Size Pipe

A plumber must use the known dfu values of fixtures to locate correct sizing information in the codebooks. Codebooks provide tables listing the dfu values of typical fixtures and particular pipe sizes. Figure 18-1 shows a typical fixture drain and trap-sizing table based on the dfu value of specific fixtures. This type of table is used to calculate dfu values for individual fixtures and bathroom groups.

(Based on International Plumbing Code)

Fixture Type	DFU Value	Minimum Trap Size
Automatic clothes washing machine/commercial ¹	3	2"
Automatic clothes washing machine/residential	2	2"
Bathroom group/1.6gpf (6.061pf) toilet ⁶	5	N/A
Bathroom group/toilet more than 1.6gpf (6.061pf) ⁶	6	N/A
Bathtub with or without shower head or whirlpool ²	2	1½"
Bidet	1	1¼"
Combination sink and tray (Note: This is a single commercial pot sink)	2	1½"
Dental lavatory	1	1¼"
Dental unit or cuspidor	1	1¼"
Dishwasher/domestic (residential) ³	2	1½"
Drinking fountain (Note: Also for an electric water cooler)	½	1¼"
Emergency floor drain	0	2"
Floor drain	2	2"
Kitchen sink/domestic (residential)	2	1½"
Kitchen sink/domestic (residential) with garbage disposal and/or dishwasher	2	1½"
Laundry tray/1 or 2 compartments	2	1½"
Lavatory	1	1¼"
Shower	2	1½"
Sink	2	1½"
Urinal	4	4
Urinal/1gpf (3.79lpf) or less	2 ⁵	4
Wash sink/per faucet/circular or multiple use	2	1½"
Water closet (toilet) tank type/public or private use	4 ⁵	4
Water closet (toilet)/private use/1.6gpf (3.79lpf)	3 ⁵	4
Water closet (toilet)/private use/more than 1.6gpf (3.79lpf)	4 ⁵	4
Water closet (toilet)/public use/1.6gpf (3.79lpf)	4 ⁵	4
Water closet (toilet)/public use/more than 1.6gpf (3.79lpf)	6 ⁵	4

¹Use a codebook for sizing continuous and semi-continuous flow when a trap is larger than 3".

²There is not a fixture unit value increase when a bathtub has a shower head and/or a whirlpool.

³Use a codebook for sizing continuous and semi-continuous flow for regulations on calculating fixture unit values for fixtures not listed or for fixtures with intermittent flow.

⁴Trap size shall be the same size as fixture outlet.

⁵The fixture unit values must be used when calculating the load of a building drain and building sewers. A lesser value cannot be used unless the lesser value is proven through testing.

⁶For fixtures added to a group value, add that particular fixture unit value to the group value.

Figure 18-1 Typical drainage fixture unit chart

TIP Many answers to questions on a licensing exam are located within a sizing table or are listed in the footnotes of a sizing table in a codebook.

Bathroom Groups

A bathroom group (Figure 18–2) is often referred to as a full bath. A bathroom group is defined by the IPC as:

A group of fixtures consisting of a water closet, lavatory, bathtub or shower, including or excluding a bidet, emergency floor drain, or both. Such fixtures are located on the same floor level. (International Plumbing Code, Chapter 2, “Definitions”)

The type of toilet must be known when the dfu value of a bathroom group is calculated. Notice in Figure 18–1 that there are several listings for a water closet. Codebooks separate toilets into categories based on (1) gallons per flush (gpf), (2) whether the toilet is a tank type, and (3) the occupancy (use) of the bathroom. There are two categories of use: public and private. Gpf ratings also fall into two categories: toilets that use 1.6 gpf and toilets that use more

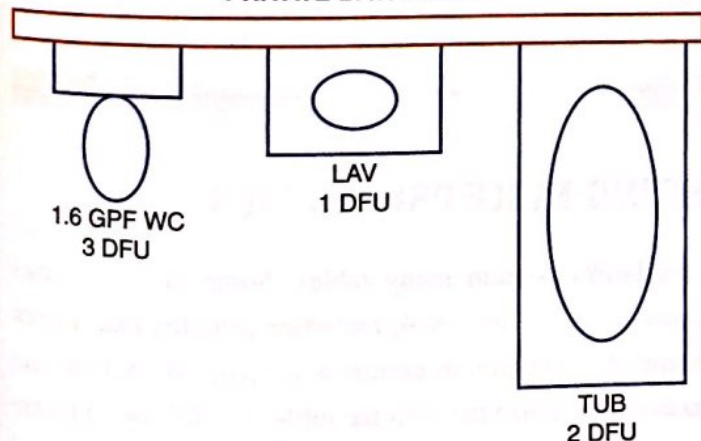
than 1.6 gpf. Urinals also have different dfu values based on the gallons of water discharged per flush.

The bathroom fixtures in Figure 18–2 equal 6 dfus when calculated individually, but if we calculate the same fixtures as a single bathroom group, the dfu value is 5. This is an allowable deduction because the group is used by a single occupant and it is highly unlikely that all three fixtures would be used simultaneously. This dfu deduction is important when sizing a DWV system.

If another fixture is added to the bathroom group, the dfu deduction for the group remains in effect, but the additional fixture must be calculated at its full dfu value. For example, many residential bathrooms include two lavatories. If we add a second lavatory to the bathroom group in Figure 18–2, the dfu for the bathroom group remains 5, and the additional lavatory’s dfu is 1. This brings the dfu total to 6 for a private full bathroom that includes two sinks, one 1.6 gpf type toilet, and one tub.

TIP The total dfu value for a bathroom group may vary from the one shown in this lesson if your code uses a higher dfu value for a water closet than the private 1.6 gpf type used in Figure 18–2. Be sure to check your local codebook.

PRIVATE BATHROOM



- Individually calculated = 6 drainage fixture units
- Calculated as a bathroom group = 5 drainage fixture units

Figure 18–2 Certain fixture types can be calculated as a bathroom group and receive a drainage fixture unit deduct than if each fixture were calculated individually

Sizing Specialized Piping

Any specialized piping arrangements—such as wet venting, common venting, battery venting, and indirect flow from equipment—are not only sized with standard tables but require the use of other tables and codebook text. The dfu value of each fixture is still obtained from a table similar to that shown in Figure 18–1, but the pipe sizes for some portions of a DWV system must recognize the sizing limitations of overriding codes. The sizes listed in the tables do not consider the installation specifics of a job site, and some minimum standards listed in a codebook can be made obsolete by overriding codes. Notice the footnotes in

Figure 18–1 and the relevant references to the footnotes within the table; these footnotes indicate special conditions and must be included in a sizing approach. Indirect waste from equipment or specialized fixtures is often calculated as **continuous** or **semicontinuous flow**. These scenarios require the use of a codebook and knowledge of the flow rate of the specific fixture or equipment.

TIP Never use a sizing table without recognizing that other codes may make the minimum pipe sizes that are listed irrelevant. Overriding codes for minimum sizes such as a toilet dictate the minimum size regardless of the dfu value.

BRANCH, DRAIN, AND SEWER SIZING TABLES

Two common tables are used to size a horizontal branch, waste stack, building drain, and building sewer once each individual fixture or bathroom group has been assigned its dfu value. Sizing begins where the most upstream fixture or bathroom group discharges into the system. Just because a codebook allows a certain pipe size based on dfu value, it may not be the minimum pipe size allowed by code. See the following example of an overriding code.

Example:

A toilet has a dfu value of 3, and a table in a codebook allows a pipe size of 2" based on the 3 dfu load.

Overriding code: A water closet has a minimum drain size of 3", and this code overrides the sizing table.

Figure 18–3 shows a typical sizing table listed in a codebook for branches and stacks. Figure 18–4 is used for sizing a building drain, building sewer, and branches that connect to a building drain. It is important to separate these two tables because the building drain must be sized to receive discharge from the waste stack, and the

building sewer must be sized to receive discharge from the entire building.

Using Code Tables Together

Notice that Figure 18–4 includes a column indicating the slope of pipe. Codebooks regulate the minimum fall per foot based on a range of pipe sizes. The table in Figure 18–5 assists plumbers in using tables like the one in Figure 18–4. Notice in Figure 18–5 that pipe sizes between 1 1/4" and 2 1/2" have a minimum slope of 1/4" per foot. If you refer to Figure 18–4, you'll notice that there are no sizing options in the columns for 1/16" and 1/8" fall per foot for any pipe sizes between 1 1/4" and 2 1/2". This is because, according to Figure 18–5, it is illegal to install pipe in those sizes with a slope of less than 1/4" per foot. All codebooks include a corresponding text section that explains each table. For example, if a table is identified as 709.1, then paragraph 709.1 is associated with that table.

TIP The footnote in Figure 18–4 provides an example of how codebooks often list regulations. This footnote indicates that an overriding code exists, and any allowable dfu values listed in the table must recognize that the minimum pipe size for a water closet is 3".

SIZING TABLE PROCEDURES

Codebooks contain many tables. Some, like the tables shown in 18–3 and 18–4, are more complex than others. Some of the numerous columns and rows are not relevant to every pipe size listed in the table. The following procedure shows how to use the tables shown in Figures 18–3 and 18–4. Study the explanations here to interpret the numbers (sizes and dfu values) you see in each column, and to understand how the columns and rows are cross-referenced.

(Based on International Plumbing Code)

Pipe Size	Total per Horizontal Branch ¹	Stacks ²		
		Total for One Branch Interval	Total for Stack 3 Stories or Less	Total for Stack More than 3 Stories
1½"	3	2	4	8
2"	6	6	10	24
2½"	12	9	20	42
3"	20	20	48	72
4"	160	90	240	500
5"	360	200	540	1100
6"	620	350	960	1900
8"	1400	600	2200	3600
10"	2500	1000	3800	5600
12"	2900	1500	6000	8400
15"	7000	Footnote 3	Footnote 3	Footnote 3

¹Does not include building drain branches. Use Figure 18-4 for building drain, building sewer, and branches of building drain sizing

²Size stacks based on combined fixture unit totals at each branch interval or story. Stacks can be reduced as the fixture unit load decreases, but can never be reduced less than half the diameter of the largest size of the stack required

³Sizing load based on design criteria

Figure 18-3 Sizing charts are different for branches that connect to stacks than for branches that connect to a building drain

PROCEDURE

To use the sizing chart in Figure 18-3:

Column 1: Pipe Size

Indicates the minimum pipe size to locate after calculating the dfu load of a single fixture, entire branch, or stack; also verifies how many dfus can discharge into a pipe size. You must know either the dfu load or the pipe size, and cross-reference the known information to locate the unknown data. For example, if an existing pipe size is known, follow that row across to the relevant column to the right to locate the maximum dfu load that particular pipe size can handle.

Column 2: Total per Horizontal Branch

This is the maximum number of fixture units that can discharge into the pipe sizes listed in column 1. The range between minimum and maximum allowable fixture units that can discharge into a pipe size is the amount between what is listed as the smaller pipe size in each row of column 1. For example, if the maximum dfu load for 2½" pipe is 12 and the maximum for 3" is 20, any calculated dfu load between 13 and 20 can discharge into a 3" branch that connects to a waste stack.

Column 3: Total for One Branch Interval

This amount refers to the dfu load that can discharge into a specific interval of a waste stack. This column must be

(Based on International Plumbing Code)

Pipe Size	Slope per Foot			
	1/4" Slope	1/8" Slope	1/4" Slope	1/2" Slope
1 1/4"	N/A	N/A	1	1
1 1/2"	N/A	N/A	3	3
2"	N/A	N/A	21	26
2 1/2"	N/A	N/A	24	31
3"	N/A	36	42	50
4"	N/A	180	216	250
5"	N/A	390	480	575
6"	N/A	700	840	1000
8"	1400	1600	1920	2300
10"	2500	2900	3500	4200
12"	3900	4600	5600	6700
15"	7000	8300	10,000	12,000

*Minimum size building drain serving a water closet (toilet) is 3".

Figure 18-4 Sizing charts for building drains, building sewers, and branches that connect to a building drain have columns indicating the slope of pipe

(Based on International Plumbing Code)

Pipe Size	Minimum Slope
2 1/2" or smaller	1/4" per foot
3" through 6"	1/8" per foot
8" or larger	1/16" per foot

Figure 18-5 Minimum slope based on fall per foot is regulated by code and is used when sizing pipe in tables listed in a codebook similar to Figure 18-4

compared to the second column, because a waste stack must be at least the same size as the largest, most upstream branch that connects to it. A stack might have to be made larger than the connecting horizontal branch. Comparing the dfu allowance in column 2 for any pipe size indicates

that the stack cannot handle the same dfu load as a branch, with 3" providing an exception. For example, if the maximum dfu load for 2 1/2" listed in column 2 is 12, and the maximum dfu load that can discharge into a 2 1/2" stack is 9, the waste stack would have to be increased to 3" because column 3 shows that a 3" stack can receive up to 20 fixture units at each interval.

Column 4: Total for Stack 3 Stories or Less

This column refers to a waste stack with a maximum of three branch intervals and is used to size an entire stack based on the calculated load of all branches that connect to the stack. Most tables include a footnote explaining that the stack can be reduced as it travels upward through a building, but cannot be reduced to any size less than half the diameter of the largest size required at the lowest point of the stack. For example, if the base of a stack is 4" and the highest branch interval is discharging 2 fixture units, the highest branch interval would be 1 1/2" based on the dfu load. However, because the lower size is 4", the upper cannot be reduced below a 2" pipe size. As mentioned earlier, overriding codes can make the dfu value sizing method irrelevant.

Column 5: Total for Stack More Than 3 Stories

This column is similar to column 4, except it regulates a waste stack with more than three branch intervals.

PROCEDURE

To use the sizing chart in Figure 18-4:

Column 1: Pipe Size

Column 1 lists a range of pipe sizes. This column suggests that the building drain and building sewer can be 1 1/4" based on the dfu load, but there are usually overriding codes that mandate them to be larger. Some codes state that no building sewer can be smaller than 4", and others state that no DWV buried below ground can be smaller than 2". This column serves the same use as column 1 in Figure 18-3.

Column 2: 1/16" Slope

This column concerns pipes that are allowed to have a minimum slope of 1/16" per foot. The first row in this column that lists dfu values is 8" pipe, because most codes do not allow pipe smaller than 8" to be installed with so little slope.

Column 3: 1/8" Slope

This column is similar to column 2, except that it pertains to piping that can be installed with 1/8" per foot slope. The first row in this column that lists dfu values is 3" pipe, because most codes do not allow pipes smaller than 3" to be installed with this slope.

Column 4: 1/4" Slope

This column is similar to columns 2 and 3, except that it addresses 1/4" per foot slope. Notice that all pipe sizes listed in the first column are included in this column. This is because all of the pipe sizes are allowed to be installed with 1/4" per foot slope; the code regulates minimum but not maximum slope. Some codes do regulate the maximum slope on a waste arm portion of a fixture drain so the trap weir is never placed above the centerline of the connecting vent fitting. For other types of drains, some state codes may allow installation using more slope than what is listed as minimum slope to discharge more dfus into a certain pipe size. However, this would have to be approved by a local code official. Never use this approach to answer questions on a licensing exam unless the examiner allows.

Column 5: 1/2" Slope

This column is similar to column 4, except that it relates to pipe installed with 1/2" per foot slope. Notice the increased dfu load allowed for most pipe sizes compared to column 5. Pipe with 1/2" per foot slope can handle more discharge from fixtures than pipe with 1/4" slope. Though codebooks allow for the greater dfu load on some pipe sizes with more slope, local codes might not recognize the 1/2" slope column. A plumber may have to

get written approval from a code official to use the values in this column.

TIP Do not use this column (5) when taking licensing exams unless the question clearly states that 1/2" per foot slope is acceptable. Most exams will ask for sizing based on minimum standards.

Fixture Drain Sizing

A fixture drain serves a single fixture trap; a fixture drain installed above ground is sized based on the particular fixture being served. Some codes do not allow a pipe less than 2" in diameter to be buried, which may override the sizes listed in a table. Some codes allow a maximum of three sinks to be served by a fixture drain using one trap. Figure 18–6 illustrates a fixture drain and some sizing considerations. The sizing method for a fixture drain is as follows:

PROCEDURE

To size a fixture drain:

Step 1: Assign a dfu value for the specific fixture type from Figure 18–1.

Step 2: Locate the minimum trap and drain size from the relevant column in Figure 18–1.

Step 3: Confirm that the sizes listed do not become irrelevant by any overriding codes. Any sizes not listed in Figure 18–1 are regulated by the footnotes in the table.

Fixture Branch and Horizontal Branch Sizing

A fixture branch and a horizontal branch are defined as different segments of a DWV system. They use the same

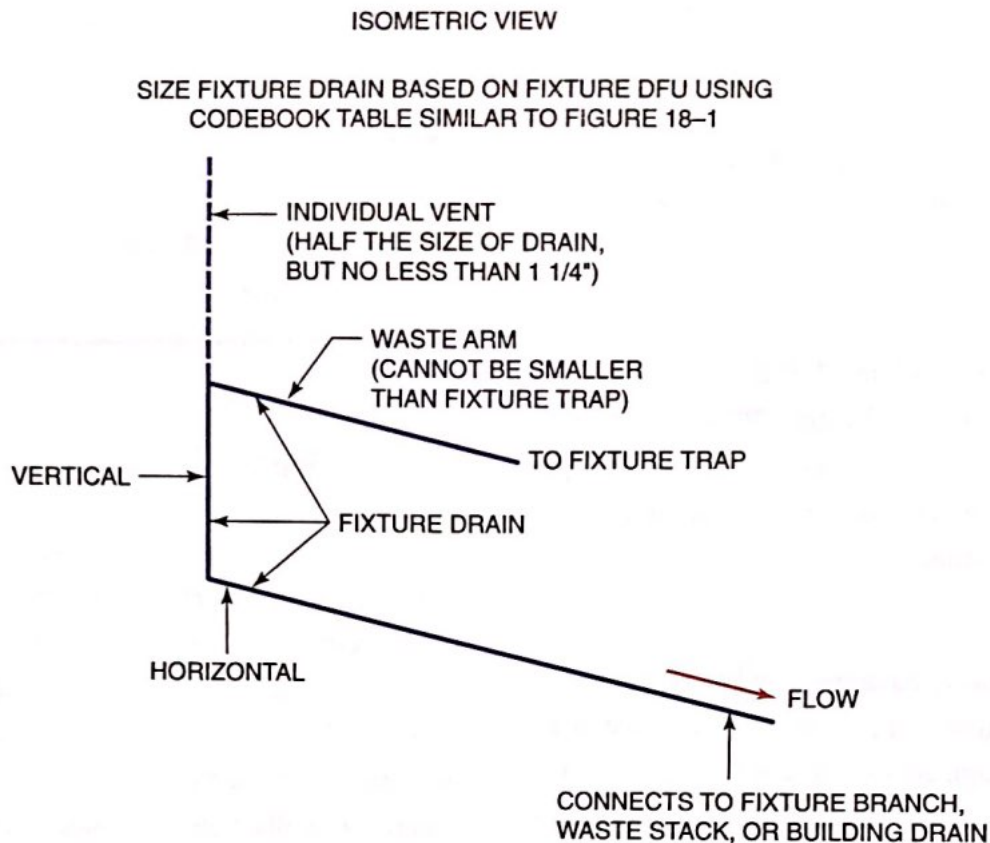


Figure 18-6 A fixture drain is sized based on the specific fixture and the use of a sizing table in a code

sizing approach, which is to calculate the dfu load discharging into the branch. The initial branch-sizing approach uses a table similar to the one shown in Figure 18-1 to calculate all dfu values of individual fixtures and groups and to determine the minimum size allowable in codebooks. If the branch connects to a waste stack, a table similar to the one shown in Figure 18-3 is used. If the branch connects to a building drain, a table similar to the one shown in Figure 18-4 is used.

The process of assigning dfu values is the same for battery-vented branches as for other branches, but that is where the similarities stop. A battery-vented horizontal branch is subject to numerous overriding codes, so it is not always sized with the same methods used for branches that are not part of a battery. Figure 18-7 illustrates the sizing approach for branches that are not part of a battery. The sizing method for branches is as follows.

PROCEDURE

To size a branch:

Step 1: Identify whether the branch connects to the building drain or waste stack. Locate the correct table based on where it connects.

Step 2: If attempting to locate the dfu load that can discharge into a known pipe size, locate that size in the table. Follow that row across the table until you find the maximum allowable dfu value for that pipe size. If trying to size the pipe based on a known dfu load, locate the dfu value or where the value falls between a certain range. Follow that row to the left of the table to locate the pipe size. If the branch connects to a building drain, be sure also to remain in the column that has the minimum allowable slope per foot of a known pipe size. If the branch connects to a waste stack, be sure you are

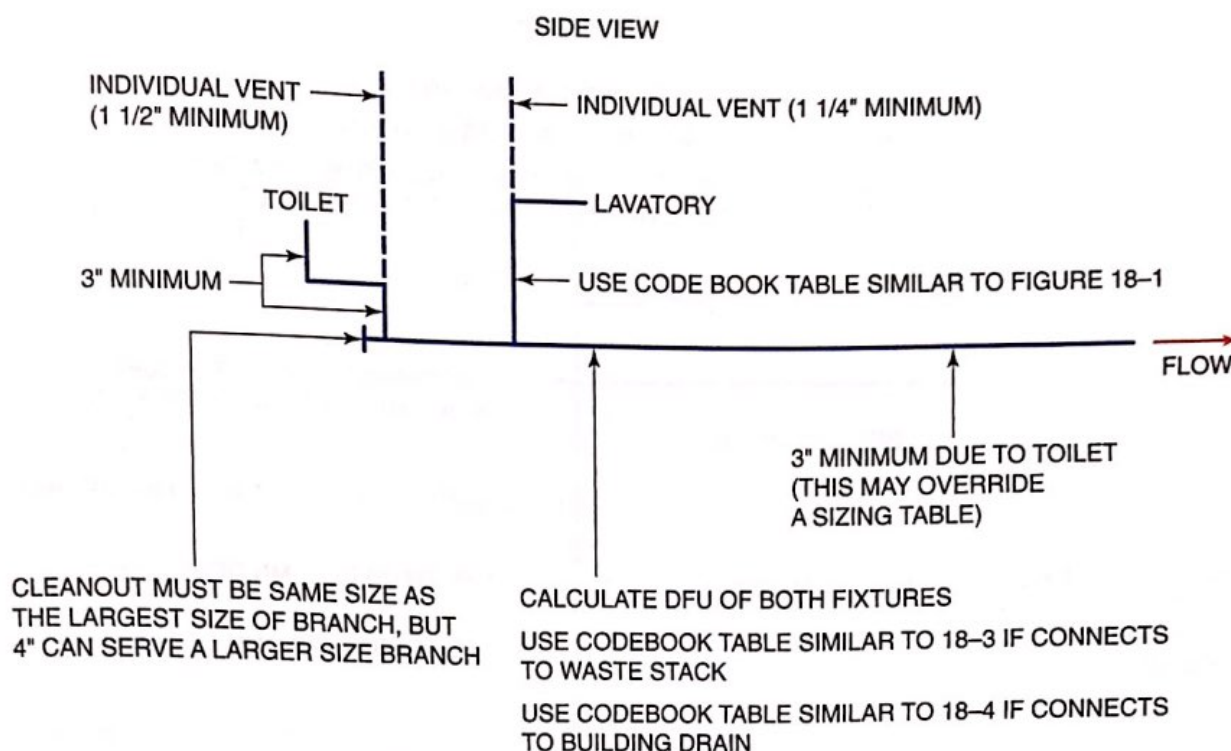


Figure 18-7 A fixture branch is sized using certain sizing tables of a codebook and often has overriding sizing codes

using the column pertaining to the branch and not the stack or the interval sizing (column 2 of Figure 18-3).

Step 3: Confirm that the size listed does not have any overriding codes.

Waste Stack Sizing

A table similar to the one shown in Figure 18-3 is used for stack sizing. The plumber must be aware of numerous overriding codes when sizing a waste stack. As previously mentioned, some codes allow a waste stack to reduce in size the higher it travels up a building, but it can never be reduced to a size that is less than half the diameter of the base of the stack size or that is less than 1 1/4". The base of the stack is sized based on the total dfu load of all branches that connect throughout the length of the stack. Each location at which a branch interval connects to the stack is sized based on the total dfu load at that point. Figure 18-8 shows a stack sized at several locations. Offsets in a waste stack are required on many projects, and the

offset areas are regulated by codes with which a plumber must be familiar before installing an offset in a stack. Any offset in a waste stack that is 45° or less from true vertical is considered vertical, and any offset that is greater than 45° from true vertical is considered horizontal. Once a horizontal offset is created, the sizes listed in a table may be irrelevant. The basic sizing method for a waste stack that does not have any offsets is as follows:

PROCEDURE

To size a waste stack:

Step 1: Ensure that there are no offsets in the stack. If there are, locate the text in a local codebook that addresses overriding codes.

Step 2: Locate the correct column of a table based on sizing either the branch interval or the entire stack. If you are trying to locate the correct size for a single branch interval connection to the stack, locate the known pipe size or the known dfu load. Follow that row across to locate the minimum pipe size or maximum dfu load. If you are trying to

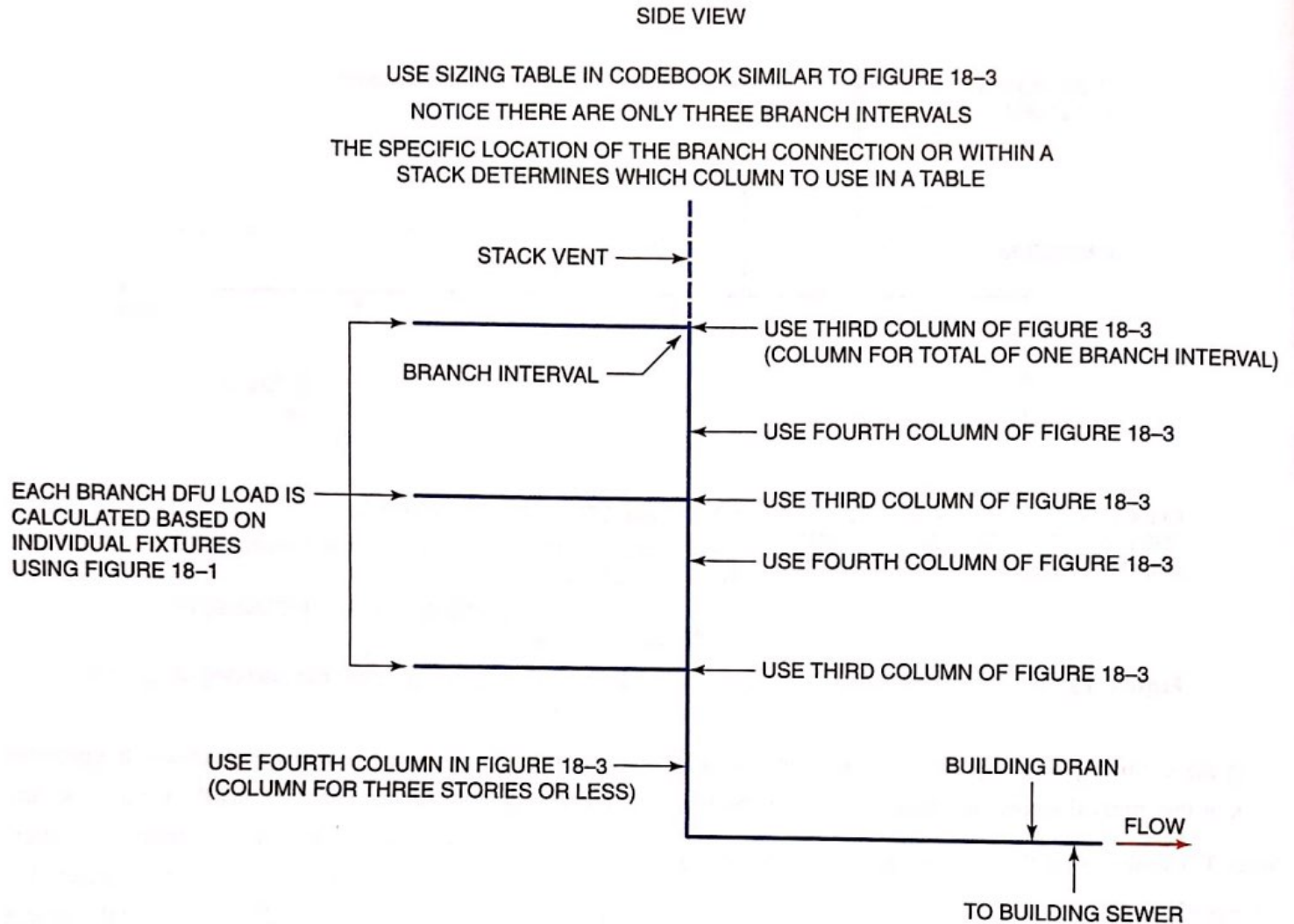


Figure 18-8 Waste stack sizing is based on the specific location within a stack and the dfu load of all branches connecting to the stack

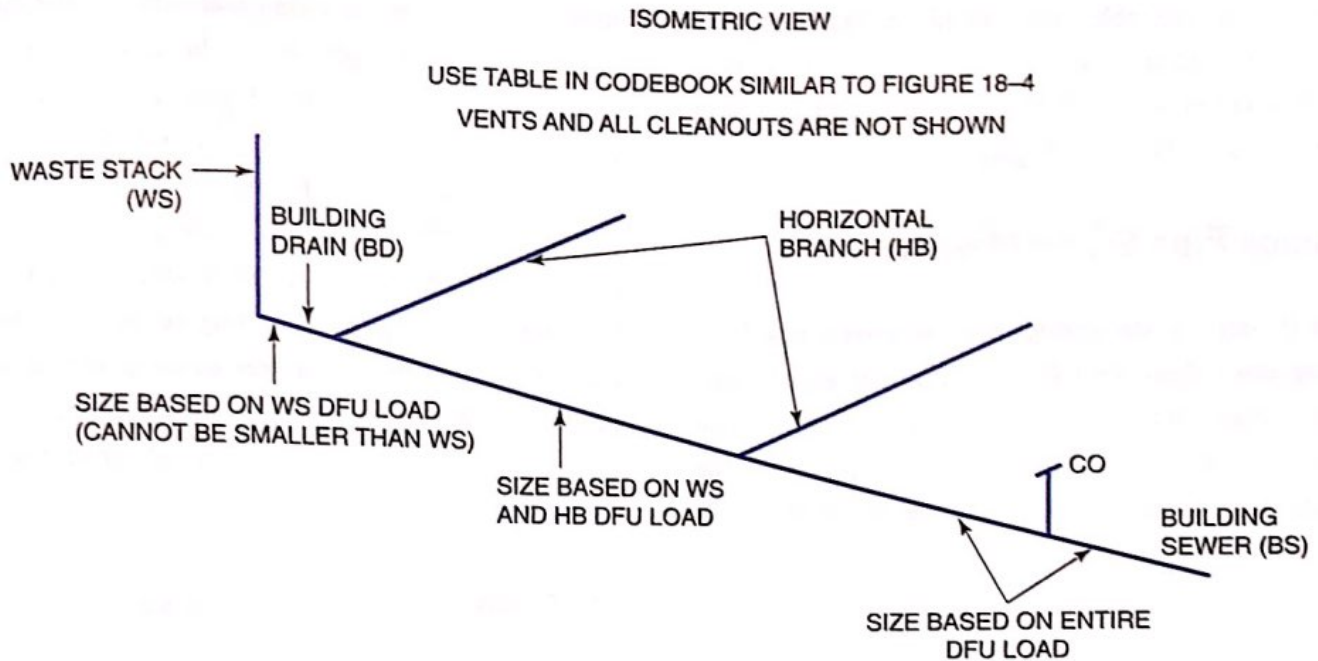
size the entire stack, make sure you are using the correct column: three branch intervals or fewer, or more than three branch intervals.

Step 3: Confirm that there are no overriding codes. One important overriding code is the inclusion of water closets in a system. Another overriding code might deal with the total number of water closets that can discharge into a waste stack. Some codes limit the number of water closets that can discharge into a single interval and for the entire stack. For example, if there are seven branch intervals, each with a water closet, and the total dfu load allows the stack to be 3", an overriding code might limit the number of toilets for a 3" stack to 6. So even though the dfu load of all the branches is

acceptable to size the stack as 3", the total number of toilets draining into the stack may increase the pipe size to 4".

Building Drain and Building Sewer Sizing

A building drain and a building sewer are two different segments of a system, but both are sized using a table similar to the one shown in Figure 18-4. Because a building drain is a major segment and the lowest horizontal portion of a DWV system, it must follow additional codes that adjust to variations in project design and anticipate the receipt of discharge from waste stacks. A sizing table lists



- Some overriding codes may make the minimum size larger than what a sizing table allows.
- Two common overriding codes include the minimum size that can be buried is 2" and BS minimum size is 4".

Figure 18-9 Sizing a building drain and building sewer is based on the dfu load at certain locations and for the entire system

general sizing scenarios, but additional codes relate to unique situations that can occur during the design or construction phase of a project. If the building drain is buried, most codes dictate that it must have at least a 2" diameter, even though the table in Figure 18-4 lists smaller sizes. If overriding codes exist, the smaller sizes are relevant only when any portion of the building drain is installed above ground. Most codes dictate that the smallest allowable building sewer is 4", and the minimum size of the building drain can be smaller than the building sewer. Figure 18-9 illustrates the sizing approach for a building drain and building sewer. The procedure for sizing a building drain and building sewer is as follows.

PROCEDURE

To size a building drain and building sewer:

Step 1: Calculate the total number of fixture units for every stack and branch that connects to the building drain.

Step 2: Locate the correct column of a table based on the slope. If the pipe size is not known, but a water closet is discharging into the system, the minimum pipe size that can be used is 3". The size of the stack is also the minimum size at which you can start a building drain sizing process when using a table. The building drain and building sewer cannot be smaller than the waste stack because a drain cannot be reduced in size from its largest upstream size. If you know the pipe size and need to confirm the dfu load, follow the known pipe size row to the relevant minimum slope column. If the dfu load is known and you are trying to locate a minimum pipe size, locate the dfu load of the known slope of an anticipated pipe size and follow that row to the column listing the minimum pipe size.

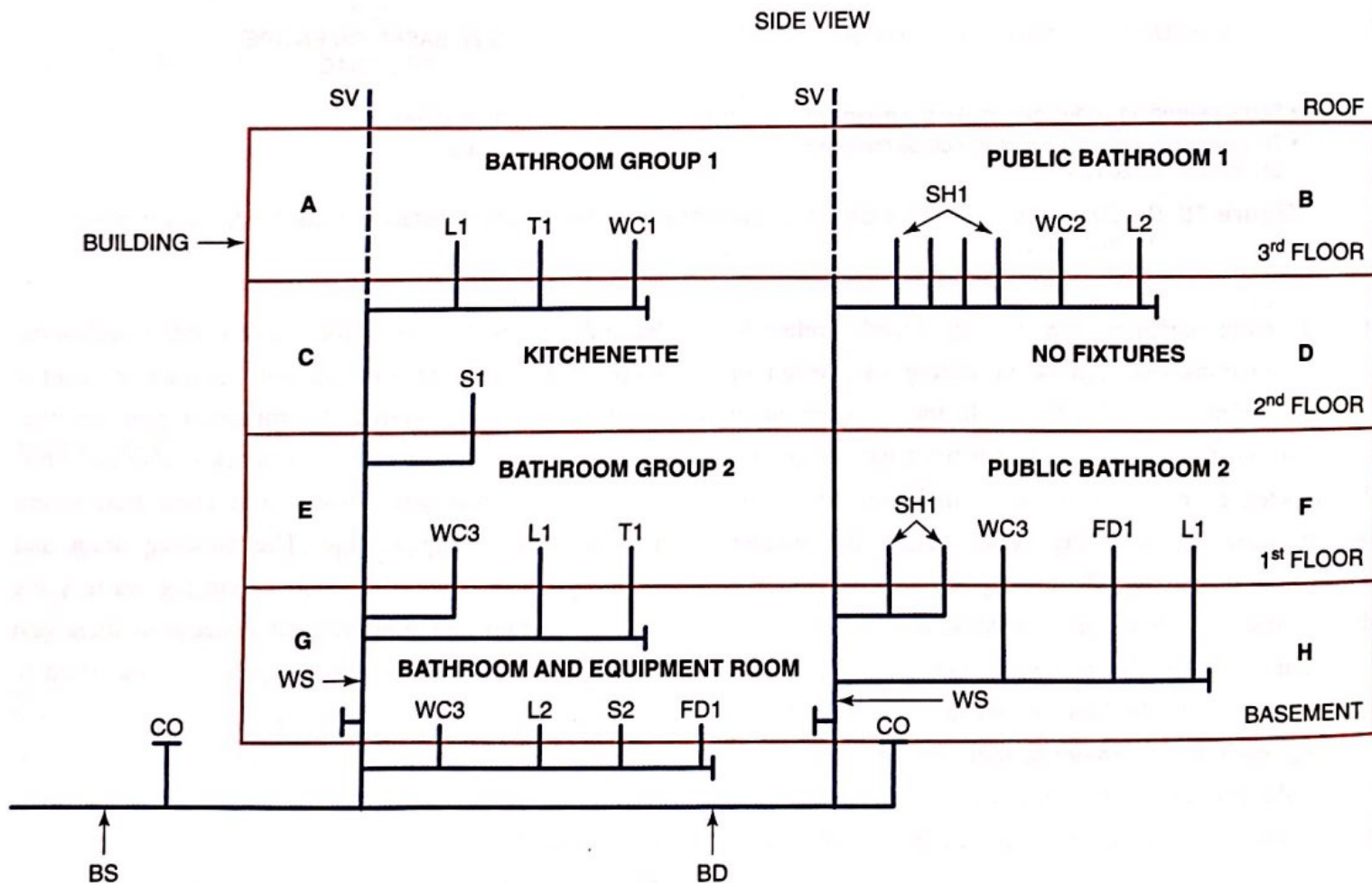
Step 3: If relevant, adjust the sizes indicated in the table to conform with overriding codes. If your code does not allow any buried drainage pipe to be less than 2", then

begin using a sizing table similar to the one in Figure 18-4 at 2" for the building drain. If your code does not allow a building sewer to be less than 4", use that starting point in a table similar to the one in Figure 18-4.

Drainage Pipe Sizing Methods

The next step in the sizing process progresses from applying dfu values for fixtures, bathroom groups, and certain segments of a drainage system to calculating an entire system. The illustrations used in this portion of the book apply to drainage sizing, and the text within each

figure will explain the sizing methods; note that not all vents required on a job site or licensing exam are included in these illustrations. Figure 18-10 illustrates an entire drainage system; Table 18-1 provides fixture specifications to accompany Figure 18-10. Figures 18-10A through 18-10H provide the corresponding details for Figure 18-10. Figure 18-11 illustrates the sizing of the building drain (BD) and building sewer (BS). Refer to previous lessons in this chapter with regard to using sizing tables for various segments of the drainage system. Also note that abbreviations are used for clarity within the figures.



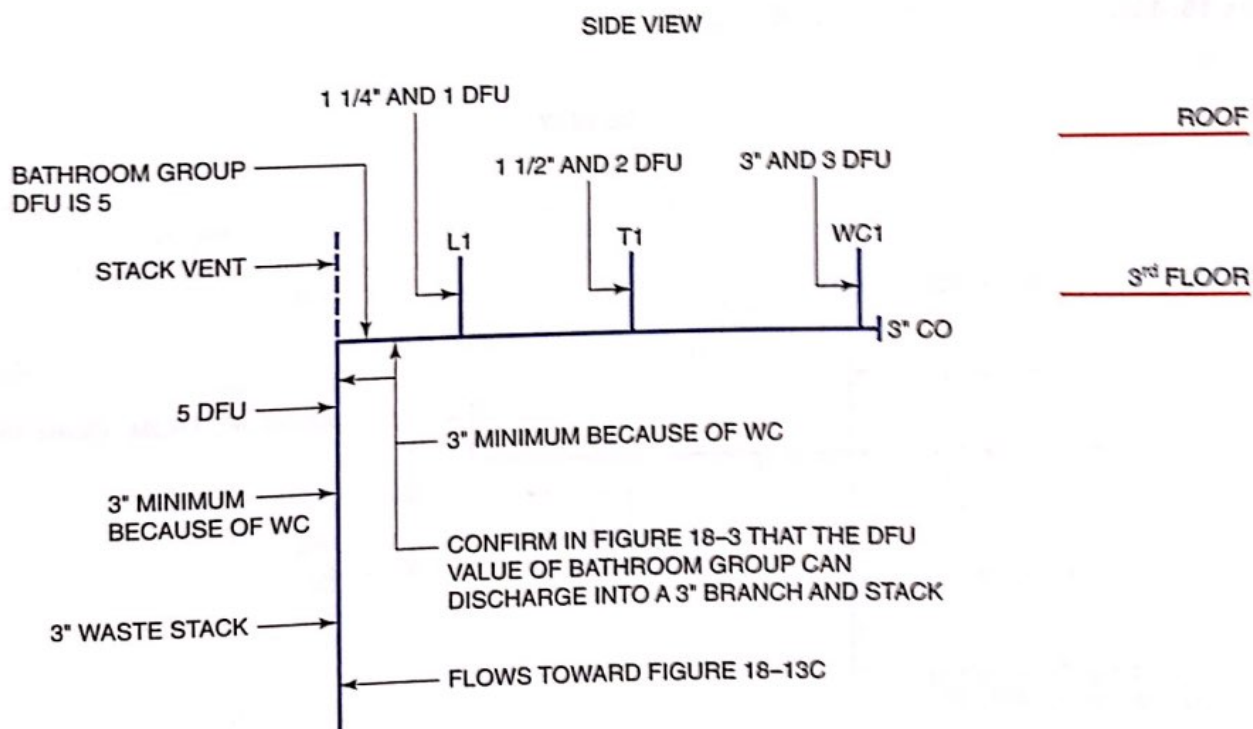
- The alphabetical indications in the illustration are detailed in Figures 18-10A through 18-10H.
- See Table 18-1 for abbreviations and specification of fixture types.

Figure 18-10 An entire drainage system is sized based on each fixture, bathroom group, and total calculated dfu load at certain locations of the drainage system

Table 18-1 Abbreviations and Fixture Specifications for Figure 18-10

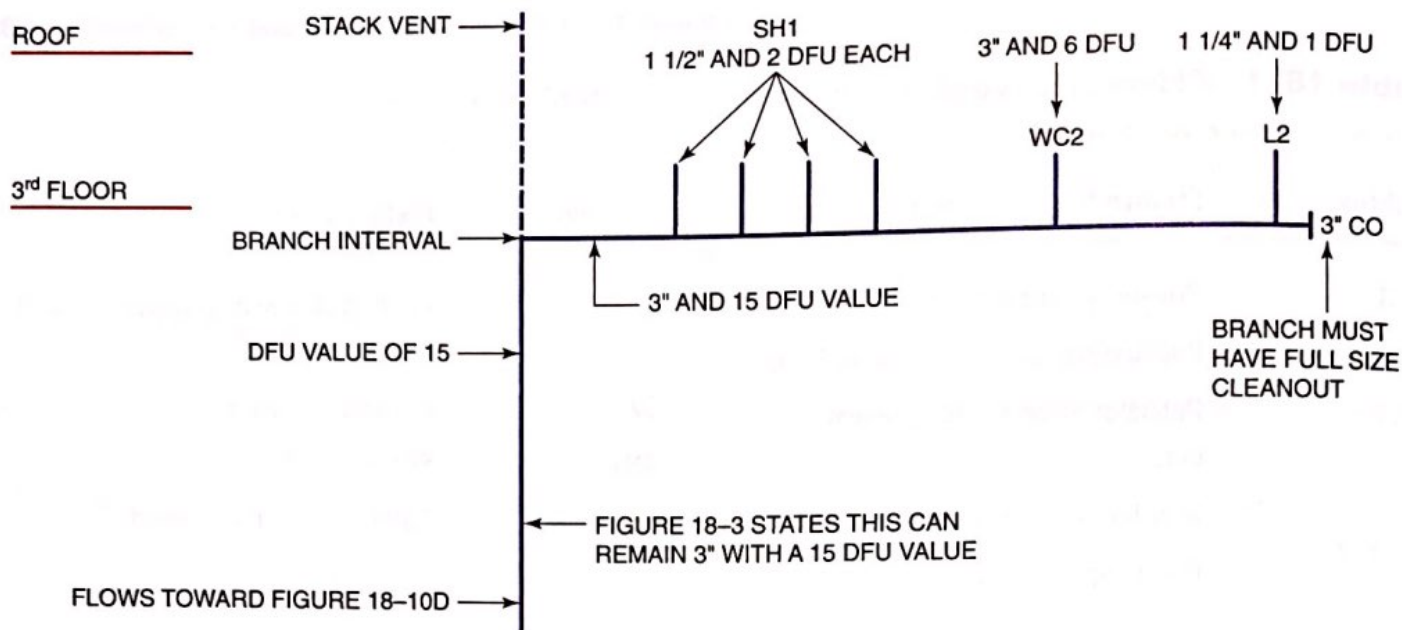
Abbreviation	Fixture Specification	Abbreviation	Fixture Specification
WC1	Private water closet, 1.6 gpf	S1	Kitchen sink with garbage disposal and dishwasher
WC2	Public water closet, more than 1.6 gpf	S2	Laundry tray (sink)
WC3	Public or private tank-type water closet	SH1	Shower stall
L1	Non-handicap lavatory	T1	Bathtub with showerhead
L2	Handicap lavatory	FD1	Floor drain

Note: Use dfu values and sizes listed in Figure 18-1.



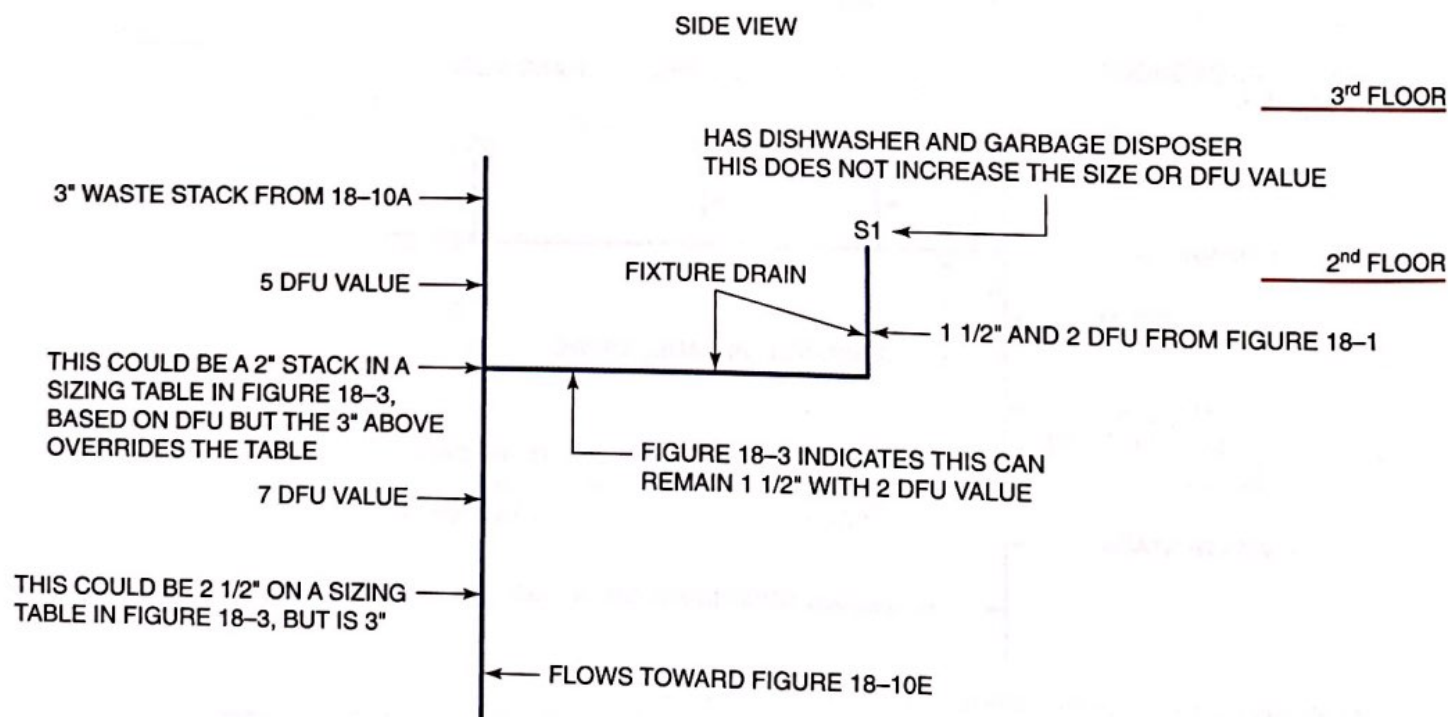
- Calculating each fixture dfu value results in a total of 6 dfu value.
- This layout is considered a Bathroom Group with a 1.6 gpf toilet and is calculated as having a 5 dfu value.
- Toilet minimum 3" size overrides sizing codes in a code book table.
- Figure 18-3 allows a total of 20 dfus to discharge into a 3" branch and branch interval of a waste stack.

Figure 18-10A Detail view of section A of Figure 18-10



- Figure 18-1 lists each fixture dfu and minimum trap size.
- The minimum trap size for shower in Figure 18-1 is 1 1/2", but some codes state 2" minimum.
- Minimum pipe size for a toilet is 3" and will override a dfu sizing table in a codebook.
- A Waste Stack having three intervals or less allows a 48 dfu value to be 3" in Figure 18-3.

Figure 18-10B Detail view of section B of Figure 18-10



- 3" Waste Stack from Figure 18-10A dictates the minimum size of this portion of the stack.
- 1 1/2" Fixture Drain size can be installed connecting to the 3" Waste Stack.
- Existing stack size overrides the minimum sizes of the table in Figure 18-3.

Figure 18-10C Detail view of section C of Figure 18-10

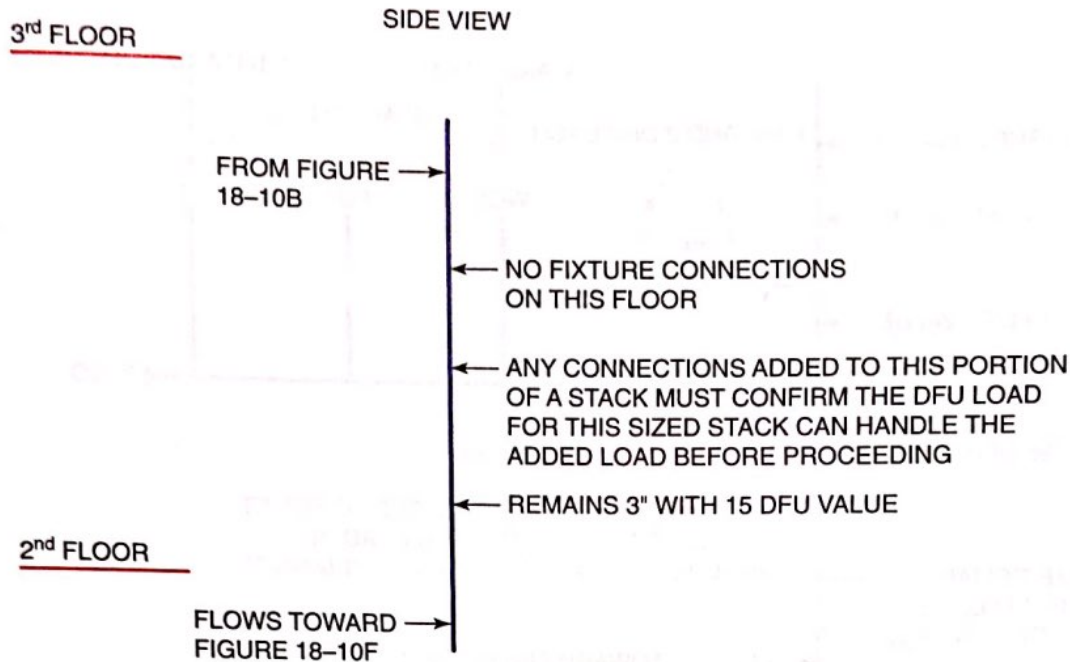
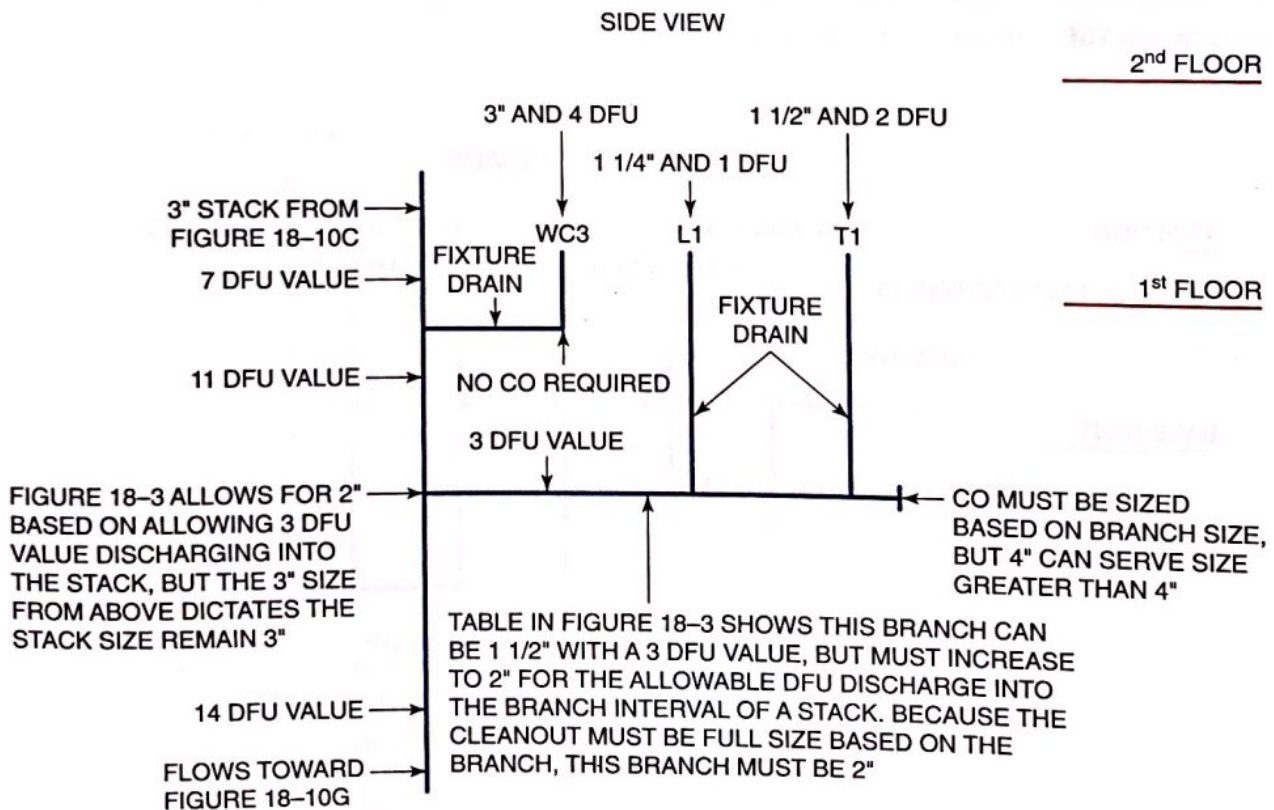


Figure 18-10D Detail view of section D of Figure 18-10

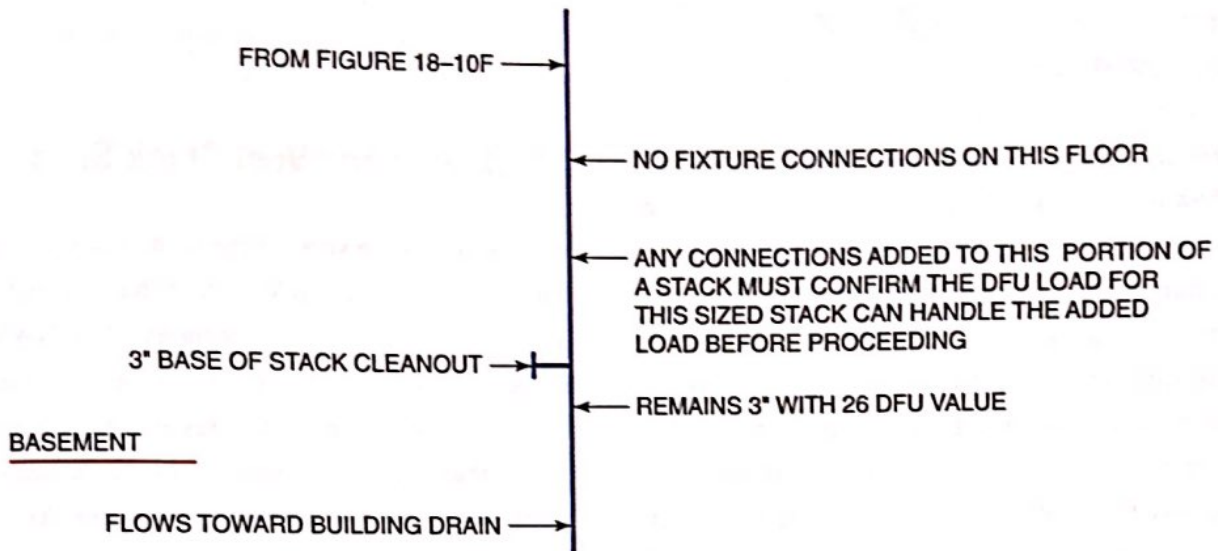


- Cleanout code stating it must be full sized based on the largest size of a branch overrides dfu sizing.
- WC3 does not require a CO because it is a Fixture Drain and the removal of the toilet is a CO.
- Stack size could be 2 1/2" based on dfu value, but must remain 3" from above floor size.

Figure 18-10E Detail view of section E of Figure 18-10

1st FLOOR

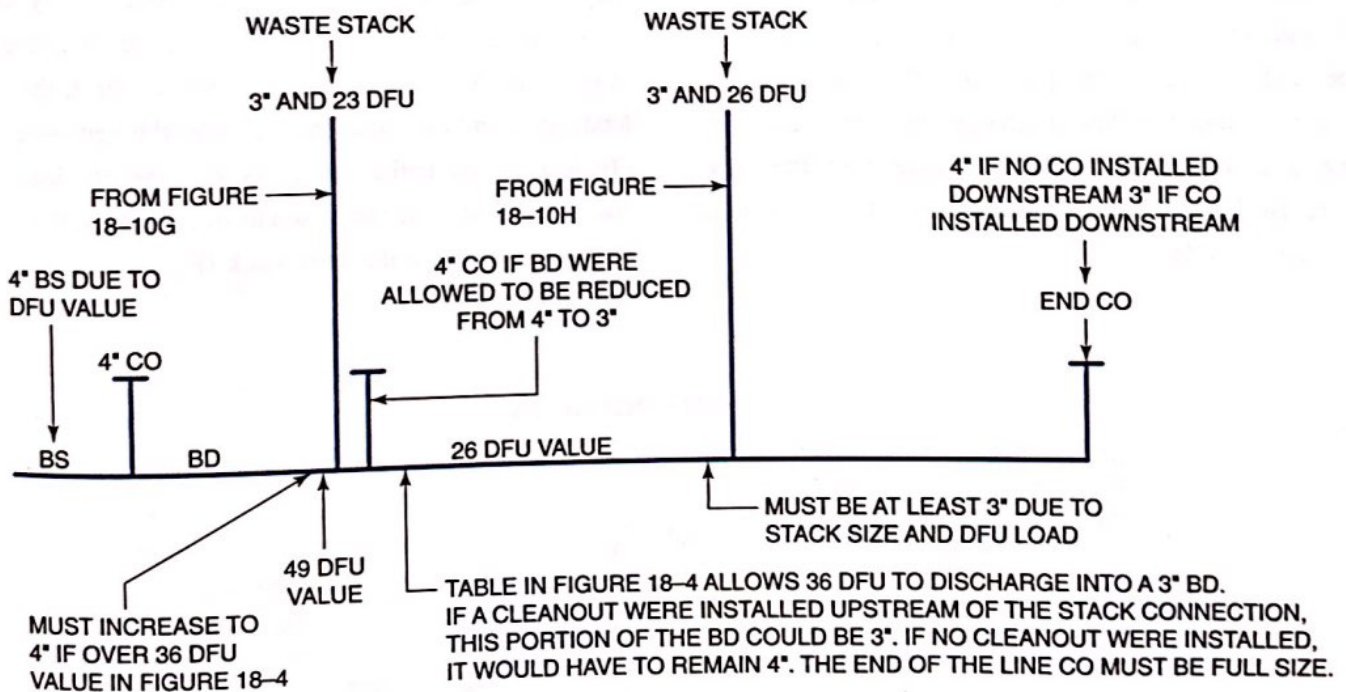
SIDE VIEW



- The total dfu load of this stack is used to size Building Drain.

Figure 18-10H Detail view of section H of Figure 18-10

SIDE VIEW



- Some codes mandate that a BS must be at least 4".
- Some codes allow a BD to be reduced if a full size CO is installed serving the larger downstream size.
- Some codes may not allow a drain buried below ground to be smaller than 2".

Figure 18-11 Building drain and building sewer sizing from Figures 18-10A through 18-10H

VENT SIZING

This chapter discusses the common types of vents and their sizing methods. Unlike a drain, which receives a dfu load and is sized to let water and solids flow through a pipe, a vent discharges the effects of the dfu load and provides airflow to and from a drain. Sizing tables included in codebooks use the dfu values of the drainage system to indicate the minimum vent size. As with drain sizing methods, overriding vent codes can make information in sizing tables irrelevant. The initial sizing approach must recognize some basic regulations. Two such regulations state that no vent can be smaller than 1 1/4", and all dry vents cannot be less than half the diameter of the drain they serve. A wet vent is sized differently than a dry vent and has a separate table in the codebooks. A loop vent and a circuit vent are vents for a battery-vented branch, and they might be sized differently by some codes than other branch vents. In colder climate regions, an overriding code relates to the size of the vent that penetrates the roof. This regulation is known as a frost closure (or enclosure) code, and it increases the pipe size of a smaller vent to prevent the moisture that discharges from the vent from freezing and closing the inside diameter of the vent. Figure 18-12 illustrates a vent increase to adhere to a frost closure code.

SAFETY ALERT If a vent becomes obstructed with frost, the DWV system will not function as designed.

Stack Vent and Vent Stack Sizing

A stack vent is the vent for the waste stack. A vent stack is the main vent of a DWV system that connects with numerous vents from other portions of a DWV system. Branch vents typically connect to the vent stack on the same floors on which the fixtures are located. Some codes dictate that a stack vent must be the same size (undiminished in size) as the waste stack. If a code does allow the stack vent to be reduced based on the size of the waste stack, it cannot be reduced to smaller than half the diameter of the size at the base of the waste stack, and in no case can it be smaller than 1 1/4". Other codes dictate that a stack vent and a vent stack are sized based on the length they travel and the total dfu load of the drainage system.

A vent can terminate to open air (outside) or connect to other vents. When two or more vents connect, their dfu loads are combined and often change the vent size. The dfu load of the entire waste stack is the dfu load of a stack vent. The same table used to size a stack vent is commonly used to size the vent stack (Figure 18-13). Most

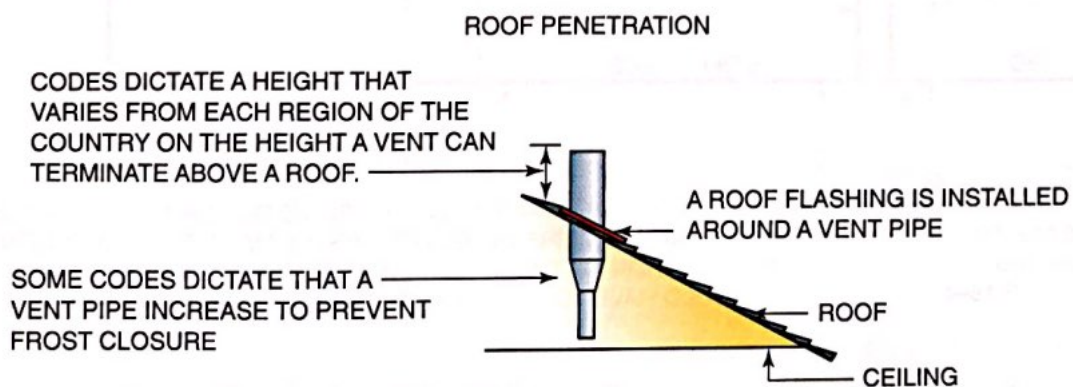


Figure 18-12 A vent may be required to increase in colder climates to prevent frost from closing the inside diameter of the vent

(Based on International Plumbing Code)

Stack Size	Maximum Developed Length of Vent in Feet*						
	DFU Total	1½" Pipe	1½" Pipe	2" Pipe	2½" Pipe	3" Pipe	4" Pipe
1¼"	2	30	0	0	0	0	0
1½"	8	50	150	0	0	0	0
1½"	10	30	100	0	0	0	0
2"	12	30	75	200	0	0	0
2"	20	26	50	150	0	0	0
2½"	42	0	30	100	300	0	0
3"	10	0	42	150	360	1040	0
3"	21	0	32	110	270	810	0
3"	53	0	27	94	230	680	0
3"	102	0	25	86	210	620	0
4"	43	0	0	35	85	250	980
4"	140	0	0	27	65	200	750
4"	320	0	0	23	55	170	640
4"	540	0	0	21	50	150	580

*Measure developed length from the point vent connects with drain to its termination point

Figure 18-13 Typical vent sizing table located in a codebook

codebooks list more pipe sizes than those shown in this table; however, in this section, we will focus on building your understanding of sizing basics—not every pipe size. As with some drainage sizing tables, a zero in the column and row indicates that the corresponding portion of the table is irrelevant. The following steps show how to use the sizing table in Figure 18-13. All step-by-step numerical references to columns move from left to right.

PROCEDURE

To use the sizing table in Figure 18-13:

Step 1: Locate the size of the waste stack in column 1. Although most of the stack sizes have numerous listings, the 1 1/4" size has only one option. The multiple listing

for most stack sizes allows different selections based on varying job conditions.

Step 2: This column lists the maximum dfu value of a certain pipe size. Follow the row of a certain stack size to column 2. Notice that the listings increase as you search down the column for a particular pipe size. For example, there are four listings for a 3" stack size; the first listing has the smaller dfu value.

Step 3: This column contains 2" and smaller waste stack sizes that are served by a 1 1/4" vent. Follow the row of a certain stack size and dfu value to column 3. This provides the maximum distance the stack vent or vent stack can travel based on the size and dfu value you selected. Notice, in the two rows for 2" pipe size, that the distance

a vent can travel decreases as the maximum dfu values increase. This column is for minimum vent size serving the selected waste stack size. If a licensing exam asks for minimum sizes and distances, you would use this column. If a job site installation requires greater distances for a specific stack and dfu value, you can move to the columns to the right to increase vent size and travel distance. This sizing approach is the same for all pipe sizes.

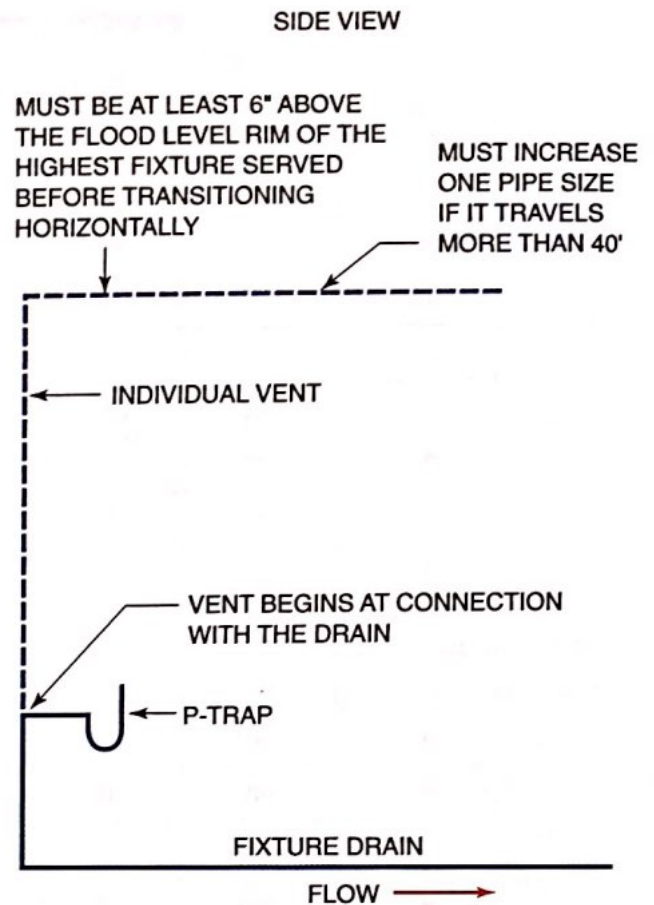
Step 4: This column provides minimum distances for 2 1/2" and 3" stacks being served by a 1 1/2" vent. The use of this column is the same as described in Step 3.

Step 5: This column provides minimum distances for a 4" stack being served by a 2" vent. The use of this column is the same as described in Step 3.

Individual Vent Sizing

The size of an individual vent typically can be half the diameter of the drain it serves, but no less than 1 1/4" diameter. Some codes limit the distance a certain size of individual vent can travel before it must increase in size. Codes might require a vent that travels more than 40 feet to increase one pipe size; that increased size begins from its point of origin with the drain. Using the 40'-0" code as an example, a codebook sizing table may allow a 2" vent based on the dfu load. But if that vent travels 50'-0", the increased pipe size would require a 2 1/2" vent.

Other vent types are sized in the same manner as an individual vent, even though they are not classified as individual vents. The dry vent serving a wet vented branch and the dry vent serving a common vented piping configuration are sized by most codes as individual vents. Figure 18-14 is an individual vent sizing illustration that follows the code stating that if a vent travels more than 40'-0", that vent must increase one pipe size above what is typically required. Check your local code for compliance with, or variations from, Figure 18-14.



*INDIVIDUAL VENT IS SIZED BASED ON BEING HALF THE DIAMETER OF THE DRAIN IT SERVES BUT CANNOT BE SMALLER THAN 1 1/4" DIAMETER

*IF VENT TRAVELS MORE THAN 40', IT MUST INCREASE ONE PIPE SIZE

*INCREASED PIPE SIZE MUST BEGIN WHERE THE VENT CONNECTS WITH THE DRAIN

Figure 18-14 Some codes require a vent to increase one pipe size if it travels more than 40'-0"

Common Venting

When two fixture drains are located on the same floor and connect either at the same height or at different heights to the same vertical drain, they form a common vented configuration. If the two fixtures connect to the same vertical drain at different heights, the middle section is a vertical wet vent. Sizing the middle section, when the two

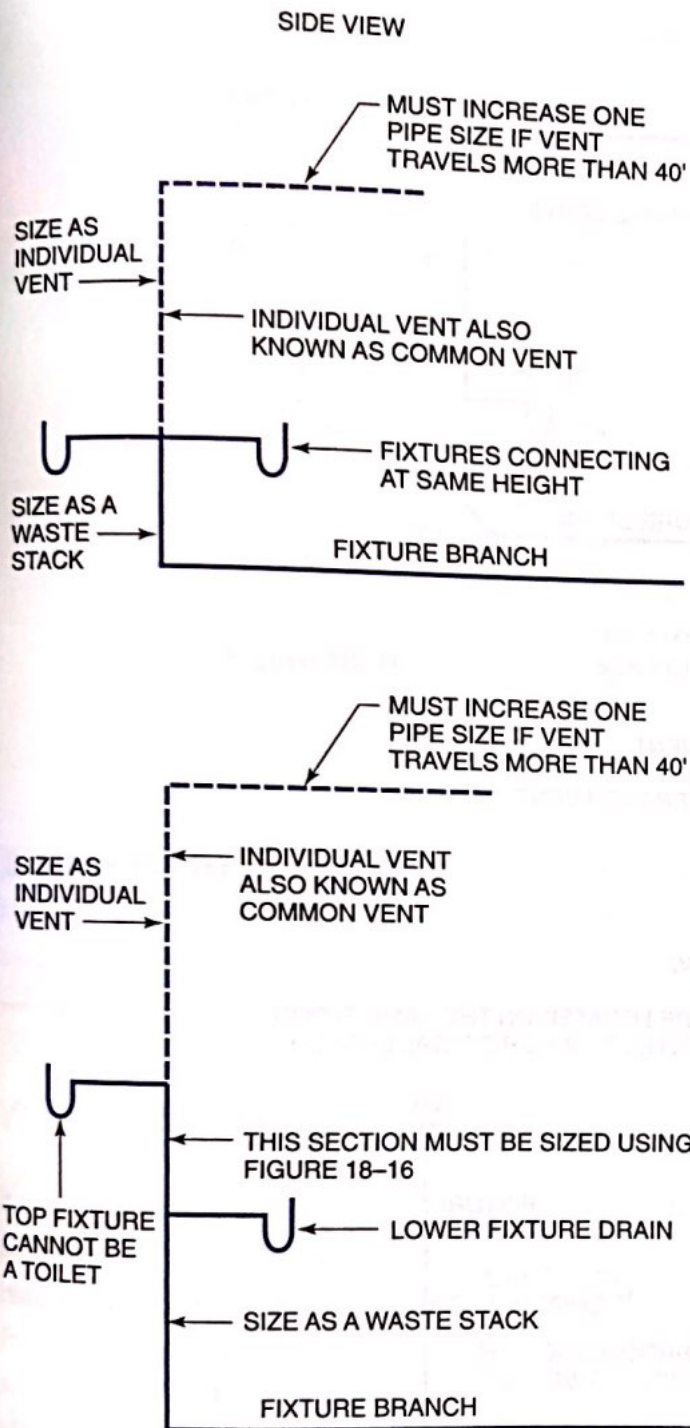


Figure 18–15 Common venting is formed by two fixture drains connecting either at the same height or at different heights on the same floor

branches connect at different heights, is accomplished using a specific table in a codebook.

Specific regulations govern common venting. Some codes state that a toilet cannot discharge into the top

(Based on International Plumbing Code)

Drain Size	DFU Maximum
1½"	1
2"	4
2½"–3"	6

Figure 18–16 Sizing table for the wet vented portion of a common vent piping arrangement

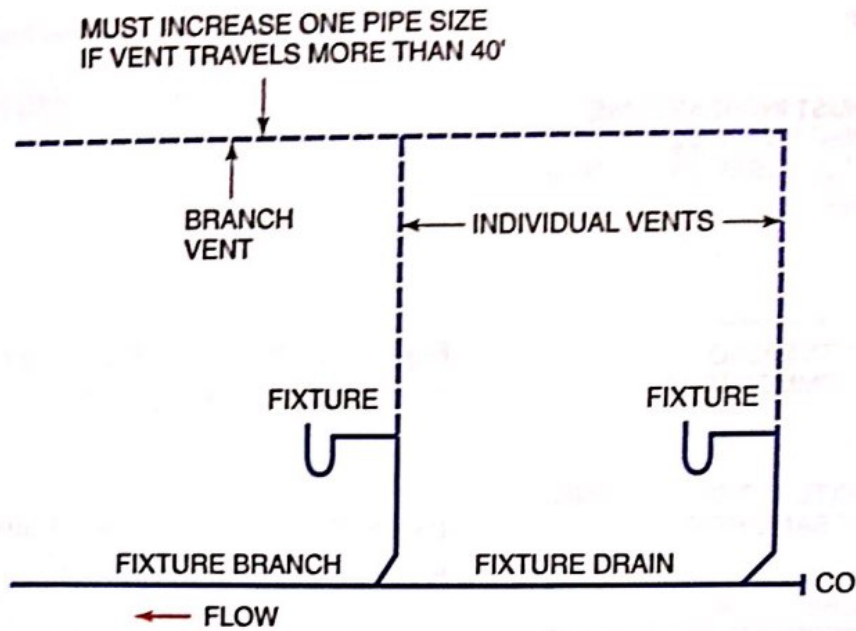
fixture drain when the two drains connect at different heights. Some codes only allow the two branches to be at the same level if both serve certain fixture types.

Figure 18–15 illustrates a common vent configuration using an individual vent. Figure 18–16 illustrates a sizing table for a common vented pipe arrangement, indicating the vertical wet vent size and its maximum allowed dfu.

Branch Vent Sizing

A branch vent serves as a vent for a drainage branch. A branch vent is sized based on the diameter of the drainage branch, the dfu value it is responsible for discharging, and the length it travels. If two individual vents serving fixtures that discharge into the same drainage branch connect, they form a branch vent. The dfu values of the two individual vents are combined to become the dfu load of the branch vent. Some codebooks have a specific sizing table for this type of vent. Figure 18–17 illustrates two individual vents connecting to form a branch vent. Figure 18–17 is an example of a code dictating that the branch vent must increase one pipe size because it travels more than 40'-0". Some codes allow installation of an air admittance valve (AAV) to serve as a branch vent. Most codes that allow an AAV for this application mandate that a relief vent be installed before the first fixture of the branch. Figure 18–18 illustrates a drainage branch being vented with an AAV and relief vent.

SIDE VIEW



*BRANCH VENT CANNOT BE LESS THAN HALF THE DIAMETER OF FIXTURE BRANCH AND IN NO CASE LESS THAN 1 1/4" DIAMETER

*SOME CODES DICTATE THAT A BRANCH VENT MUST INCREASE ONE PIPE SIZE WHEN TWO INDIVIDUAL VENTS CONNECT TO FORM A BRANCH VENT

Figure 18-17 Branch vent

ISOMETRIC VIEW

- AAV CAN ONLY SERVE FIXTURES THAT ARE LOCATED ON THE SAME FLOOR
- AAV CAN ONLY SERVE FIXTURES CONNECTED TO A HORIZONTAL BRANCH

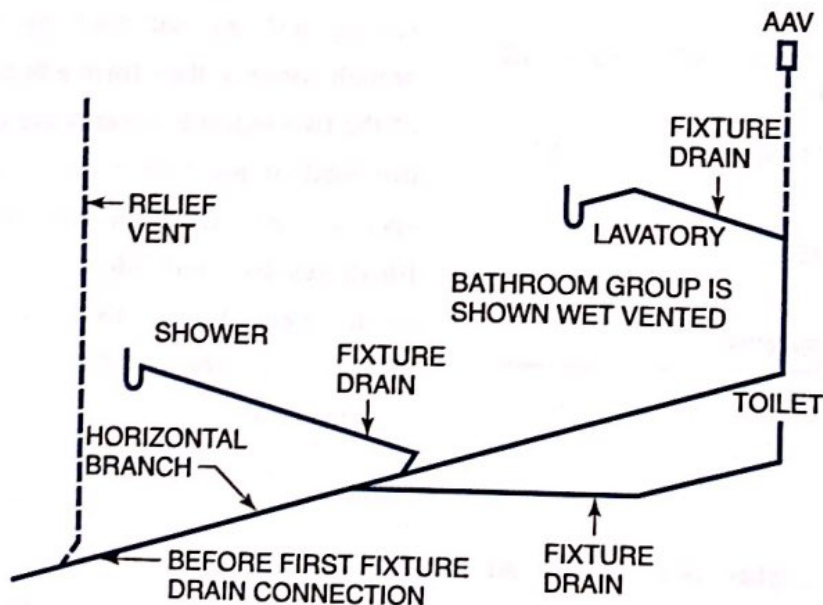


Figure 18-18 Some codes mandate that a relief vent be installed when an air admittance valve is used to vent a drainage branch

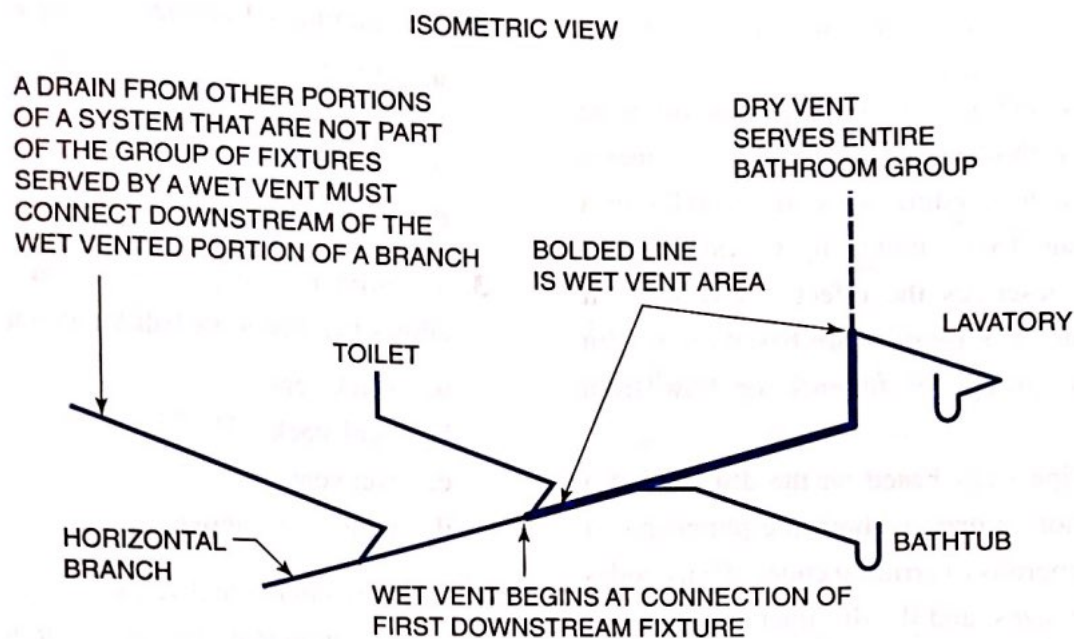


Figure 18-19 A wet vent configuration eliminates the installation of multiple individual vents

SAFETY ALERT Incorrect installation of an AAV can form excessive pressure in a drainage system and cause sewer gas to be forced out of a trap.

Wet Vent Sizing

A wet vent piping arrangement may not be allowed by all codes. A wet vented portion of a drainage system still requires a dry vent. This type of wet venting differs from a common vented arrangement and uses different sizing tables within a codebook. Most codes do not allow the toilet to be the most upstream fixture of a wet vented branch. If a toilet is one of the fixtures within a wet vented configuration, the minimum size of the dry vent that can even be considered is 1 1/2" diameter. This is due to the toilet's minimum drain size of 3"; code regulations require a vent to be at least half the diameter of the drain it serves. The size of the wet vented portion is based on the dfu value of the fixture or fixtures

draining into the wet vented portion of the system. A sizing table in a codebook lists allowable dfus that can drain into any particular pipe size. Any other fixtures or branches that are not part of the wet venting arrangement typically must connect downstream of the wet vented portion of the drainage system. Figure 18-19 illustrates a wet vented piping arrangement, and Figure 18-20 is an example of a typical sizing table that would appear in a codebook.

(Based on International Plumbing Code)

Wet Vent Size	DFU Maximum
1 1/2"	1
2"	4
2 1/2"	6
3"	12

Figure 18-20 A table in a codebook lists the allowable dfu load that can drain through certain wet vent sizes

SUMMARY

Sizing a DWV system is complex and can often be difficult. It begins with identifying the specific segments of a system and understanding the correct tables in a codebook. A drainage fixture unit (dfu) is a value placed on a fixture that describes the effect it has when it discharges into a drain. Pipe sizes are based on the dfu values of fixtures, groups of fixtures, or flow from equipment.

Tables listing pipe sizes based on the dfu load of a DWV system cannot be used without the plumber first recognizing the numerous overriding codes. Many codes establish minimum sizes, and the dfu load is used when no overriding codes exist or when the load increases the minimum pipe sizes based on certain codes. One such code that sets the minimum pipe size is for a water closet; a toilet must have a minimum pipe size of 3". Even if a codebook allows for a smaller size based on the dfu value, the minimum size remains 3". This minimum drain size for a toilet also dictates that it be served by a 1 1/2" minimum-sized vent (check local code for verification). The basis for a vent size is that no dry vent shall be less than half the diameter of the drain it serves, and no less than 1 1/4". Vents are sized based on their role in providing airflow to the drainage system. When assigning dfu values, the sizing approach begins with the most upstream fixtures and progresses downstream, ending with the building sewer.

TEST YOUR KNOWLEDGE

1. The smallest diameter pipe that can be installed in a DWV system is:
 - a. 2"
 - b. 1 1/2"
 - c. 1"
 - d. none of the above
2. The minimum drain size serving a toilet is:
 - a. 2 1/2"
 - b. 2"
 - c. 4"
 - d. none of the above
3. The primary sizing method for an individual vent allows the pipe to be half the diameter of the:
 - a. stack vent
 - b. vent stack
 - c. wet vent
 - d. none of the above
4. When two individual vents connect, and each serves a drain that discharges into the same horizontal branch, they create a:
 - a. vent stack
 - b. stack vent
 - c. branch vent
 - d. none of the above
5. Sizing a waste stack must, at least, include the dfu load of each branch interval and:
 - a. the number of water closets that discharge into the stack
 - b. the minimum size of the stack vent
 - c. the dfu load of the building sewer
 - d. all of the above
6. A bathroom group consists of a water closet, a bathtub or shower, and:
 - a. two lavatories
 - b. a bidet
 - c. a lavatory
 - d. none of the above
7. The minimum size p-trap for a laundry sink using Figure 18-1 is:
 - a. 2"
 - b. 1 1/2"

- c. 1 1/4"
 - d. none of the above
8. Minimum pipe sizes listed in a sizing table in a codebook can become irrelevant when:
- a. an overriding code exists
 - b. a company preference allows smaller sizing
 - c. an inspector allows it to be installed at a smaller size
 - d. all of the above
9. Two fixtures that are common vented and connect at different heights create a middle section that is:
- a. sized as a dry vent
 - b. always a minimum of 3"
 - c. a vertical wet vent
 - d. none of the above
10. What does the abbreviation dfu represent?
- a. drainage flow unit
 - b. designed fixture unit
 - c. designated fixture units
 - d. none of the above
11. What is the minimum individual vent size for a 2" drain?
- a. 1"
 - b. 1 1/4"
 - c. 1 1/2"
 - d. none of the above
12. What is the minimum fixture drain size serving a bathtub, using Figure 18-1?
- a. 2"
 - b. 1 1/4"
 - c. 1 1/2"
 - d. none of the above
13. A company can increase the pipe sizes but cannot _____ than the codes allow.
- a. install smaller pipe sizes
 - b. increase the minimum size of a toilet drain
 - c. discharge less dfus into a drain
 - d. none of the above
14. The drain sizing approach, when assigning dfu values, begins with:
- a. the building sewer
 - b. the building drain
 - c. the most upstream fixtures
 - d. none of the above
15. A wet vented portion of a drainage system still requires a:
- a. 3" drain
 - b. dry vent
 - c. water closet connection
 - d. all of the above
16. When two fixtures situated back-to-back discharge at different heights into one vertical drain, it is known as:
- a. common venting
 - b. a fixture drain
 - c. a horizontal wet vent
 - d. none of the above
17. When two fixtures situated side by side discharge at the same height into one vertical drain, it is known as:
- a. dual waste arm configuration
 - b. horizontal wet venting
 - c. common venting
 - d. none of the above
18. Indirect waste from equipment or specialized fixtures is often calculated as:
- a. a building drain
 - b. continuous or semicontinuous flow

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- c. a waste stack
 - d. none of the above
- 19.** When two or more vents connect, their dfu loads are _____ and often change the vent size.
- a. combined
 - b. doubled
 - c. multiplied by 1.5
 - d. none of the above
- 20.** When two fixtures situated back-to-back discharge at different heights into one vertical drain, the vertical pipe between the two fixture drain connections:
- a. must be sized according to a chart in a codebook
 - b. is a vertical wet vent
 - c. both a and b
 - d. none of the above

CHAPTER 19

Natural Gas Piping, Water Piping, and Water Heaters

OBJECTIVES

After completing this chapter, the student should be able to:

- Understand sizing methods of natural gas and water supply systems.
- Size a water heater.
- Understand different sizing approaches.

GLOSSARY

Friction loss: pressure decrease due to friction as gas or water flows through piping; can be caused by valves, fittings, devices, and the type of pipe

Hardness: total mineral content of water

Pressure drop: loss of pressure from friction or obstructions from pipe, valves, fittings, and devices

Pressure-loss method: method for sizing water pipe based on pressure loss through a system

Velocity method: method for sizing water pipe based on velocity of the flow of water through a system

SYSTEM SIZING

Sizing a piping system is not as easy as simply calculating the demand or expectations of a gas or liquid. The type of pipe, the distance the piping system covers, and the pressure must be used to determine the pipe sizes.

Sizing a water heater is easier than sizing a piping system, because it involves less data; Section 4 of this book, entitled "Water Heating," discusses numerous water heater types. Once the available energy source is determined, the selection of the water heater is based on the number of gallons of hot water that are required.

This chapter does not size systems based on a specific project but instead explains general sizing methods. A piping system or water heater sizing approach must consider specific information based on a certain project. The sizing tables and charts in this book are examples and must not be used on a specific job site. Refer to local codebooks for specific sizing requirements.

NATURAL GAS

This chapter covers basic sizing methods used to provide adequate natural gas supply to appliances and equipment. Specific sizing methods might vary by job site; plumbers must therefore consult codebook sizing tables. Two common codes are the National Fuel Gas Code (NFGC) and the International Fuel Gas Code (IFGC).

Codebooks include many different sizing tables for various job site conditions, and most codebooks place sizing information in an appendix. It is important to locate the correct table for a specific project and to keep in mind that certain engineering methods might be allowed in some areas of the country. Your local codebook should include specific sizing charts; any variation from sizing methods found in codebook tables usually needs to be submitted to a local code official for approval. If the codebook does not provide local data, the gas supplier can act as a source of local information.

The IFGC applies a general sizing consideration to minimum pipe sizes that supply all appliances and equipment, operating at the same time (simultaneously) and under maximum demand. The IFGC states this general consideration as follows:

Piping systems shall be of such size and so installed as to provide a supply of gas sufficient to meet the maximum demand without undue loss of pressure between the point of delivery and the gas utilization equipment. (Chapter 4, Section 402, Paragraph 402.1)

The point of delivery can vary depending on whether a gas meter is installed. The outlet of a meter is the most common delivery point, but if a meter is not installed, regulating devices may be considered the point of delivery by your local code. The "gas utilization equipment" described here by the IFGC is the specific appliance or equipment. The plumber must know the gas supply requirements of each appliance or piece of equipment before sizing a system. If information is not listed on a nameplate attached to the appliance or piece of equipment, the manufacturer should be contacted for necessary data. Gas appliances and equipment also list the British thermal unit (btu) requirements; refer to Section 4 of this book for a detailed explanation of btus.

TIP When referring to a manufacturer's btu information, always use the btu input (not output) data.

Sizing the System

When sizing gas pipe, consideration may be given to possible future additions to the system. Sizing means to determine the size of the mains and branches in the gas delivery system for the particular installation. Taking into account the btu per hour requirements for the individual appliances, the installer works from the gas source, which

would be the meter or an existing gas cock, to the farthest appliance. As the branch lines to appliances join the main line, the size of the pipe is increased. It is essential to start with a sketch or plan. The lengths of the branches and mains must be taken into account. Because of the low pressures at which most gases are supplied, pressure losses caused by the friction of the gas against the side of the pipe are important. Fortunately, most gas piping tables will provide a way to allow for this. Whenever possible, the gas supplier's recommendations for type and size of pipe must be followed.

This is an outline of one sizing process:

1. Obtain the following:

- the heating value in btu per cubic foot of the particular gas being used. (In our example, we'll use 1 cubic foot = 1,000 btu.)
- the specific gravity of the gas.
- the supply pressure of the gas.

2. Draw up a sketch with lengths and btuh (British thermal units per hour) requirements of the various appliances shown (see Figure 19-1).

3. Convert btuh requirements to cfh (cubic feet per hour) requirements at the terminals.

Terminal F will now equal 1,000 cfh

Terminal G will now equal 2,500 cfh

Terminal H will now equal 750 cfh

Terminal I will now equal 5,000 cfh

Terminal J will now equal 3,000 cfh

4. Calculate the length of the assembled pipe to the farthest appliance from the source. From now on, this will be the number used when calculating pipe sizes. This number remains the same even for short branches.

A to B is 250'

B to C is 100'

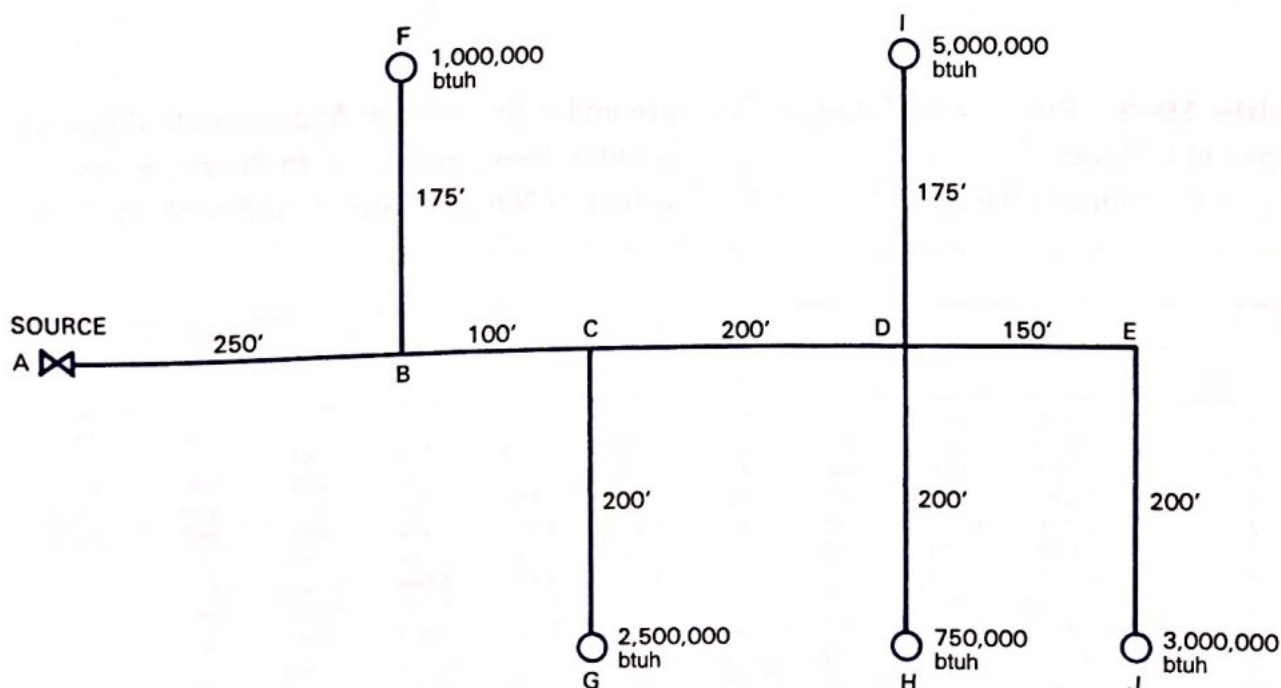


Figure 19-1 Sizing a gas piping system begins with assigning the btuh values to all appliances and equipment

C to D is 200'

D to E is 150'

E to J is 200'

The total distance is 900' to the farthest terminal, J.

- Start at the first length of pipe from the source to the first tee (Tables 19-1 and 19-2). The chart must correspond to the information you gathered in step 1. Add up the cfh requirements for all of the appliances because this piece of pipe must supply enough gas for all of them. Using the length from step 4 and the cfh requirements, read off the pipe size from the chart. Working toward the farthest appliance and subtracting the cfh requirements for appliances that are passed along the way, all of the pieces and branches may be looked up on the chart.

TIP On pipe sizes larger than 4", each fitting is given a footage equivalent. This is then added to the total pipe length. The purpose of this is to allow for the friction of the gas against the pipe walls. Friction loss, as it is called, is not significant in smaller pipe sizes.

WATER SUPPLY SIZING

Friction Loss in Pipes

To understand the loss of pressure caused by water flowing through pipe, one must consider the length and size of the pipe, the roughness of the interior, and the number and type of fittings.

In Figure 19-2, tank A is filled with water. When valve E is closed, gauges B and C show the same pressure. This is the pressure exerted by the head H, or $H \times .434$. However, when valve E is opened and water flows, gauge C shows less pressure than gauge B. This pressure loss is due to the rubbing action of the moving water against the sides of the pipe and is known as **friction loss**.

If the pipe is twice as long, the friction is twice as much. If the pipe corrodes and becomes very rough, the friction loss increases considerably. If the pipe size increases, the friction loss is reduced. This is because only that water that actually touches the side of the pipe causes friction.

Table 19-1 Pipe Sizing Table for Pressure under One Pound; Approximate Capacity of Pipes of Different Diameters and Lengths in Cubic Feet per Hour with Pressure Drop of 0.5" Water Column and 0.6 Specific Gravity (Courtesy of National Standard Plumbing Code)

Iron Pipe Size Schedule 40 (Inches)	Total Equivalent Length of Pipe in Feet										
	50	100	150	200	250	300	400	500	1000	1500	2000
1	244	173	141	122	109	99	86	77	54	44	38
1 1/4	537	380	310	268	240	219	189	169	119	97	84
1 1/2	832	588	480	416	372	339	294	263	185	151	131
2	1,680	1,188	970	840	751	685	594	531	375	306	265
2 1/2	2,754	1,952	1,591	1,379	1,232	1,123	974	869	617	504	436
3	5,018	3,549	2,896	2,509	2,244	2,047	1,774	1,587	1,121	915	793
4	10,510	7,410	6,020	5,170	4,640	4,480	3,660	3,340	2,360	1,910	1,660
5	19,110	13,480	10,960	9,410	8,440	8,150	6,660	6,070	4,290	3,480	3,020
6	31,140	21,960	17,860	15,320	13,760	13,280	10,860	9,890	7,000	5,670	4,920
8	63,310	44,740	36,380	31,220	28,020	27,040	22,120	20,150	14,250	11,550	10,030
10	113,020	79,720	64,830	55,630	49,940	48,180	39,420	35,920	25,400	20,580	17,870
12	177,450	125,180	101,790	87,350	78,400	75,650	61,900	56,400	39,890	32,320	28,060

Table 19-2 Multipliers to be Used with Table 19-1 when the Specific Gravity of Gas Is Other Than 0.60 (Courtesy of National Standard Plumbing Code)

Specific Gravity	Multiplier
.35	1.31
.40	1.23
.45	1.16
.50	1.10
.55	1.04
.60	1.00
.65	.962
.70	.926
.75	.895
.80	.867
.85	.841
.90	.817
1.00	.775
1.10	.740
1.20	.707
1.30	.680
1.40	.655
1.50	.633
1.60	.612
1.70	.594
1.80	.577
1.90	.565
2.00	.547
2.10	.535

Friction is proportional to the square of the velocity. Friction is increased by changes in the size of the pipe because of the eddies that are set up in the pipe, as shown in Figure 19-3. Eddies are air or water currents that move against a main current.

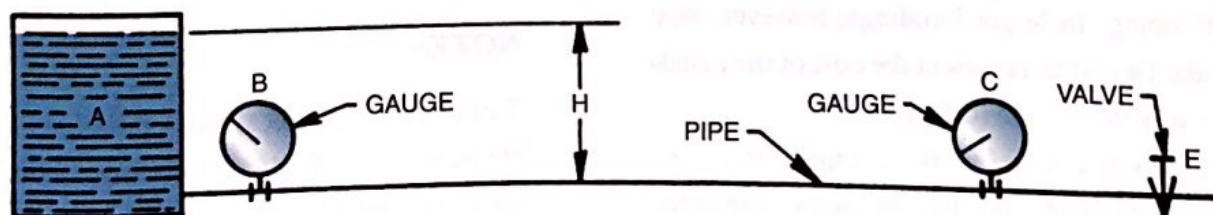


Figure 19-2 Friction loss due to water flowing through the pipe is evident when viewing pressure gauges

Water Velocity

Water has a number of properties that concern the plumber. **Hardness** is the total mineral content of the water and affects the scaling of the inside pipe surfaces. The *pH* of the water refers to the acid balance of the water; a pH of 7 is neutral. A low pH means that the water has high acid content. With the low pH, for instance, copper water tubing is liable to corrode quickly.

These factors can be controlled somewhat with water-softening equipment. The plumber can slow down the speed of the water in the pipe by increasing the size of the tubing. The slower the water flows, the less corrosion that takes place. Water that flows too fast:

- Is noisy.
- Causes water hammer.
- Causes excessive wear and corrosion, especially when water is hard, acidic, or hot (over 150°F).

Under normal conditions, velocity should be 8 feet per second (fps). If the water has a low pH (high acid), water-softening equipment, quick-closing valves, or very hot water (over 150°F), the velocity should be 4 fps.

FACTORS TO CONSIDER IN PIPE SIZING

The tasks of water supply system are to:

- Supply adequate water to any outlet under normal conditions.
- Operate in silence.

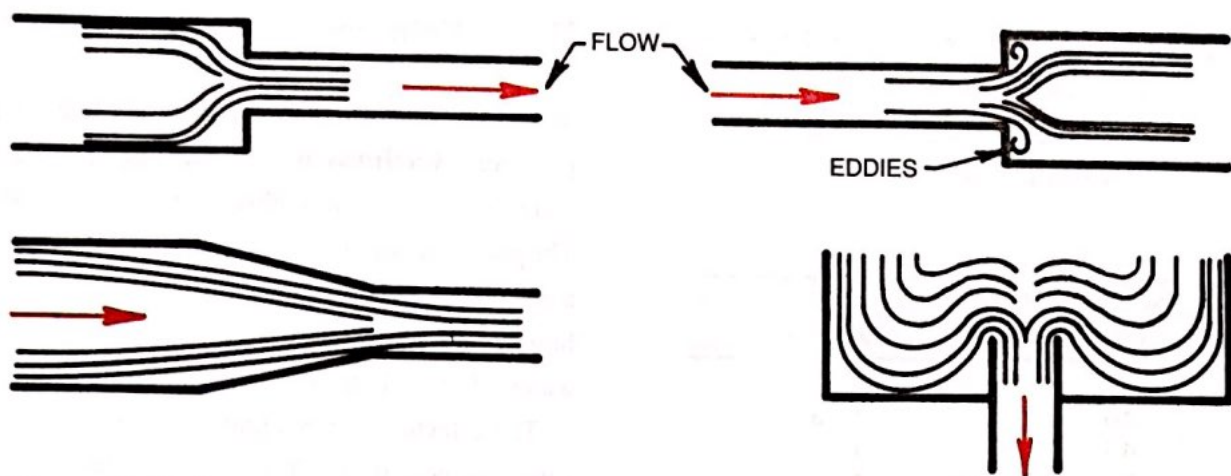


Figure 19-3 Eddies are formed as water flows through restrictions in the piping system

When a plumber “sizes a water supply system,” essentially what he/she is doing is making a material list for the fittings in the system. As the flow from two fixtures is joined together, a tee is used. The outlets to the fixtures are large enough to supply each fixture. The inlet to the tee must be large enough to supply *both* fixtures. The same is true for tees supplying groups of fixtures. Each outlet of the tee must be large enough to supply the group supplied by that outlet, and the inlet must be large enough to supply both of the groups services by the two outlets. If the plumber begins at the fixture furthest away from the water supply and works his/her way backward, sizing tees along the way, he/she will eventually end up at the water service and will be able to calculate its size from the accumulated data.

There are many different methods of pipe sizing. In home construction, most experienced plumbers will not need to go through the formal mathematics of pipe sizing. Instead, they will use their past experience to size the water supply piping. In larger buildings, however, pipe sizing can make large differences in the cost of the installation and the way the system fulfills its tasks.

There are two major methods of pipe sizing: the **pressure-loss method** and the **velocity method**. There are many other methods, as well, which are usually

variations or combinations of these two. The velocity method is acceptable for buildings of three stories or less, and it is easy to use and understand. This method is explained in detail later in this unit.

The velocity method makes some assumptions, however, which limit its usefulness. When the facts of the project exceed these assumptions, the friction-loss method should be used.

Velocity Method Assumptions

1. The building will be house-sized in area.

When the length of runs in the water supply gets longer, the friction caused by the water molecules rubbing against the sides of the pipe and fittings, and the turbulence caused by rough edges and pipe fittings, will slow the flow and reduce the pressure available at the outlets.

NOTE:

Turbulence in piping systems has been much studied and is not completely understood. It does not conform to mathematical methods. It is known that turbulence, once introduced into the water

flow, has a tremendous and unreasonable drag on that flow. Plumbers who wink at the practice of reaming water tubing should take note: "Suppose you have a perfectly smooth pipe with a perfectly even source of water. . . . All the rules seem to break down. When flow is smooth or laminar, small disturbances die out. **But past the onset of turbulence**, disturbances grow catastrophically. This onset—this transition—became a critical mystery in science" (*Chaos, Making a New Science*, James Gleick, 1987, Viking Penguin Inc.).

Un-reamed pipe creates turbulence!

2. The building will be three stories or fewer.

For each story in height (approximately 10'), the pressure that was available at the water main drops 4.34 pounds per square inch (psi). If the water pressure at the main were 65 psi at 15 stories, there would be **NO pressure** available. And, of course, at lower levels there would be less and less available as the number of floors increased.

In taller buildings, this is compensated for by having booster pumps at some floor levels. Some very tall buildings have a water tank located at the top for firefighting purposes. The level in this tank is maintained by booster pumps. The water to the floors of the building is then supplied by gravity. This may seem like a low-pressure supply system. But now the water pressure *increases* by 4.34 psi at each lower floor level. Every 10th floor or so must have a pressure-reducing valve installed to avoid damage to the terminal outlets and piping from excess pressure!

3. There will be no designed continuously running outlets.

Air-conditioning towers, manufacturing processes, and continuous irrigation processes will make the velocity system inapplicable.

4. There will be at least 40 psi of available water pressure.

Buildings with supply pressures under 40 psi are also to be sized using some other method than the velocity method.

SIZING PIPE BY THE VELOCITY METHOD

Sizing pipe by the velocity method applies to buildings of three stories or less. The water pressure available must be at least 40 psi.

Step 1. Obtain the available pressure at the main and the corrosive qualities of the water from the local authorities.

Step 2. Make a schematic drawing of the entire system. Show where the branches are located and which fixtures go with which branches. Identify all quick-closing valves, such as flushometers that require 4' per second piping.

Step 3. Refer to Table 19-3. Mark on the drawing the total water supply fixture units (wsfu) to each fixture and the hot-and-cold water valves.

Step 4. Starting from the fixture outlets, mark minimum supply sizes down from Table 19-4.

Step 5. Working from the fixtures to the service pipe, size the system according to the velocity limitation tables in Tables 19-5A and 19-5B. If the system pressure is above 40 psi, go to the nearest pipe size. If the system pressure is very close to the minimum (40 psi), and the wsfu load falls between two pipe sizes, choose the larger.

Example:

Determine the pipe size for a small home. It has a bathroom group (tub, toilet, and lavatory), an outside hose bib (a valve that may run continuously), a small washing machine, a laundry tray, and a kitchen sink. It has city water, and the municipal authority says the water is noncorrosive and has a minimum pressure of 55 psi.

Table 19-3 Load Values Assigned to Fixtures

Fixture	Occupancy	Type of Supply Control	Load Values, in Water Supply Fixture Units		
			Cold	Hot	Total
Water closet	Public	Flush valve	10.		10.
Water closet	Public	Flush tank	5.		5.
Urinal	Public	1" flush valve	10.		10.
Urinal	Public	3/4" flush valve	5.		5.
Urinal	Public	Flush tank	3.		3.
Lavatory	Public	Faucet	1.5	1.5	2.
Bathtub	Public	Faucet	3.	3.	4.
Shower head	Public	Mixing valve	3.	3.	4.
Service sink	Offices, etc.	Faucet	2.25	2.25	3.
Kitchen sink	Hotel, restaurant	Faucet	3.	3.	4.
Drinking fountain	Offices, etc.	3/8" valve	0.25		0.25
Water closet	Private	Flush valve	6.		6.
Water closet	Private	Flush tank	3.		3.0
Lavatory	Private	Faucet	0.75	0.75	1.
Bathtub	Private	Faucet	1.5	1.5	2.
Shower stall	Private	Mixing valve	1.5	1.5	2.
Kitchen sink	Private	Faucet	1.5	1.5	2.
Laundry trays (1 to 3)	Private	Faucet	2.25	2.25	3.
Combination fixture	Private	Faucet	2.25	2.25	3.
Dishwashing machine	Private	Automatic		1.	1.
Laundry machine (8 lbs.)	Private	Automatic	1.5	1.5	2.
Laundry machine (8 lbs.)	Public or General	Automatic	2.25	2.25	3.
Laundry machine (16 lbs.)	Public or General	Automatic	3.	3.	4.

Step 1. The pressure is above 40 psi. Because the water is noncorrosive, the system can be designed for 8' per second.

Step 2. The schematic drawing is shown in Figure 19-4.

Step 3. According to the load values assigned to fixtures (Table 19-3):

- a. Bathtub has 2 wsfu; 1.5 cold, 1.5 hot.
- b. Lavatory has 1 wsfu; .75 cold, .75 hot.
- c. Toilet has 4 wsfu; cold only.
- d. Outside hose bib is not on the chart.
Since it may run continuously, it should be rated at 2 wsfu.

- e. Washing machine with an 8-pound capacity has 2 wsfu; 1.5 cold, 1.5 hot.
- f. Laundry tray has 3 wsfu; 2.25 cold, 2.25 hot.
- g. Kitchen sink has 2 wsfu; 1.5 cold, 1.5 hot.

Step 4. Referring to Table 19-4, the pipe sizes from the tees to the fixtures will be:

- a. Bathtub—1/2"
- b. Lavatory—3/8"
- c. Toilet—3/8"
- d. Hose bib—1/2"
- e. Washing machine—1/2"
- f. Laundry tray—1/2"
- g. Kitchen sink—1/2"

Table 19-4 Minimum Size of Fixture Supply Pipes

Fixture or Device	Size (in.)
Bathtub	1/2
Combination sink and laundry tray	1/2
Drinking fountain	3/8
Dishwashing machine (domestic)	1/2
Kitchen sink (domestic)	1/2
Kitchen sink (commercial)	3/4
Lavatory	3/8
Laundry tray (1, 2, or 3 compartments)	1/2
Shower (single head)	1/2
Sink (service, slop)	1/2
Sink (flushing rim)	3/4
Urinal (1" flush valve)	1
Urinal (3/4" flush valve)	3/4
Urinal (flush tank)	1/2
Water closet (flush tank)	3/8
Water closet (flush valve)	1
Hose bib	1/2
Wall hydrant or sill cock	1/2

Step 5. By referring to the velocity limitation tables in Tables 19-5A and 19-5B, the rest of the building can be sized. There is a separate table for each kind of pipe. Assume that L-type copper tube is used within the house and that a K-type copper tube is used for the underground service pipe.

The tables are divided into 10 columns. From left to right:

- Column 1 lists the pipe size required.
- Column 2 lists the inside pipe diameter.
- Column 3 lists the flow in gallons per minute of that size.
- Column 4 lists the load (wsfu) for tank-type toilets.
- Column 5 lists the load (wsfu) for flush valve-type toilets.

- Column 6 lists the amount of pressure that is lost in 100'.
- Columns 7, 8, 9, and 10 are the same as columns 3, 4, 5, and 6. Columns 7, 8, 9, and 10, however, are for velocities of 8' per second. Columns 3, 4, 5, and 6 are for velocities of 4' per second.

Results: In step 4, the branches were sized from the fixtures to the tees that serve them. From the bathroom group to point A on Figure 19-4, there are 7.25 wsfu on the cold side. According to the tables under the 8 fps and flush tank toilets column, 1/2" tubing will handle 2.5 wsfu and 3/4" tubing will handle 7.3 wsfu.

Step 1. From point A to the bathroom group, there should be 3/4" tubing on the cold side. Therefore, there are 2.25 wsfu from the tee at point A to the tee in the bathroom group on the hot side.

Step 2. From point A to the bathroom group, there should be 1/2" tubing on the hot side. From point B to point A, the pipe must carry the kitchen sink, the washing machine, the laundry tray, plus the bathroom group and hose bib. On the cold side, there are 12.50 wsfu. On the hot side, there are 7.5 wsfu.

Step 3. From point B to point A on the cold side, there should be 3/4" tubing; 12.5 is closer to 7.3 than it is to 22.5.

Step 4. From point B to point A, there should be 3/4" tubing on the hot side. From point B to the street main, the cold line must carry all of the load for the building, both hot and cold. When this occurs, the total figure per fixture must be used rather than adding the individual hot and cold figures. There are 25 total wsfu for the building. Types L and K tubing will carry 22.5 and 19.5 in the 1" size, respectively.

Step 5. Therefore, the water service and the main to point B will be in the 1" size using this method.

Table 19-5A Sizing Tables Based on Velocity Limitation (Courtesy National Standard Plumbing Code)

Copper Water Tube, Type K

Nominal Size (in.)	Actual I.D. (in.)	Flow (gpm) q	Velocity = 4' per second			Velocity = 8' per second			
			Load (wsfu) 1*	Load (wsfu) 2*	Friction (psi/100') p ³ *	Flow (gpm) q	Load (wsfu) 1*	Load (wsfu) 2*	Friction (psi/100') p ³ *
			Col. A	Col. B					
½	.527	2.7	.75	—	8.5	5.4	2.3	—	31.0
¾	.745	5.5	2.3	—	5.6	11.0	6.3	—	20.2
1	.995	9.7	5.3	—	4.1	19.4	19.5	5.8	14.4
1¼	1.245	15.2	10.8	5.0	3.1	30.4	54.0	14.0	11.1
1½	1.481	21.5	25.0	7.8	2.6	43.0	98.0	34.0	9.2
2	1.959	37.6	78.0	24.0	1.8	75.2	251.0	130.0	6.5
2½	2.435	58.2	166.0	69.0	1.4	116.4	460.0	340.0	5.2
3	2.907	82.8	289.0	161.0	1.2	165.6	725.0	663.0	4.2
4	3.857	146.0	609.0	528.0	0.8	292.0	1705.0	1705.0	3.0

Galvanized Iron and Steel Pipe, Standard Pipe Size

½	.622	3.8	1.5	—	8.2	7.6	3.7	—	31.0
¾	.824	6.7	3.0	—	6.0	13.4	8.4	—	22.5
1	1.049	10.8	6.1	—	4.6	21.6	25.3	7.7	17.2
1¼	1.380	18.6	17.5	6.0	3.4	37.2	77.3	23.7	12.8
1½	1.610	25.4	37.0	9.3	2.9	50.8	132.3	52.0	10.8
2	2.067	41.8	93.0	29.8	2.2	83.6	293.0	171.6	8.4
2½	2.469	59.8	174.0	75.6	1.8	119.6	477.0	361.0	6.8
3	3.068	92.0	335.0	209.0	1.4	184.0	842.0	806.0	5.4
4	4.026	158.6	688.0	615.0	1.1	317.2	1980.0	1930.0	4.1

Schedule 40 Plastic Pipe, (PE, PVC, & ABS)

½	.622	3.8	1.5	—	6.8	7.6	3.7	—	24.2
¾	.824	6.7	3.0	—	5.1	13.4	8.4	—	18.0
1	1.049	10.8	6.1	—	3.7	21.6	25.3	7.7	13.2
1¼	1.380	18.6	17.5	6.0	2.8	37.2	77.3	23.7	9.6
1½	1.610	25.4	37.0	9.3	2.3	50.8	132.3	52.0	8.2
2	2.067	41.8	93.0	29.8	1.7	83.6	293.0	171.6	6.1
2½	2.469	59.8	174.0	75.6	1.4	119.6	477.0	361.0	4.8
3	3.068	92.0	335.0	209.0	1.1	184.0	842.0	806.0	3.8
4	4.026	158.6	688.0	615.0	0.8	317.2	1930.0	1930.0	2.8

*¹ Col. A applies to piping that does not supply flush valves.*² Col. B applies to piping that supplies flush valves.*³ Friction loss, p, corresponding to flow rate, q, for piping having fairly smooth surface condition after extending service, applying the formula:

$$q = 4.57 (p) (d)$$

Table 19-5B Sizing Tables Based on Velocity Limitation (*Courtesy National Standard Plumbing Code*)

Copper and Brass Pipe, Standard Pipe Size

Nominal Size (in.)	Actual I.D. (in.)	Flow (gpm) q	Velocity = 4' per second			Velocity = 8' per second			
			Load (wsfu) 1*	Load (wsfu) 2*	Friction (psi/100') p ³ *	Flow (gpm) q	Load (wsfu) 1*	Load (wsfu) 2*	Friction (psi/100') p ³ *
			Col. A	Col. B			Col. A	Col. B	
½	.625	3.8	1.5	—	6.8	7.6	3.7	—	24.2
¾	.822	6.6	3.0	—	5.1	13.2	8.4	—	18.0
1	1.062	11.0	6.3	—	3.7	22.0	26.4	8.0	13.3
1¼	1.368	18.3	16.8	6.4	2.8	36.6	75.0	22.7	10.0
1½	1.600	25.2	36.3	9.3	2.3	50.4	130.0	51.0	8.4
2	2.062	41.6	92.0	29.5	1.7	83.2	291.0	170.0	6.2
2½	2.500	61.2	181.0	80.0	1.4	122.4	492.0	376.0	4.9
3	3.062	92.0	335.0	209.0	1.1	184.0	842.0	807.0	3.9
4	4.000	158.0	685.0	611.0	0.8	316.0	1920.0	1920.0	2.9

Threadless Copper and Red Brass Pipe (TP)

½	.710	4.9	2.0	—	5.9	9.8	5.3	—	20.8
¾	.920	8.3	4.2	—	4.4	16.6	13.2	5.7	15.5
1	1.185	13.7	9.0	—	3.3	27.4	44.0	10.5	11.7
1¼	1.530	22.9	28.9	8.3	2.4	45.8	110.0	40.0	8.5
1½	1.770	30.6	55.0	14.5	2.1	61.2	181.0	80.0	7.2
2	2.245	49.4	126.0	48.5	1.6	98.8	369.0	240.0	5.6
2½	2.745	74.0	245.0	125.0	1.3	148.0	631.0	537.0	4.4
3	3.334	109.0	421.0	305.0	1.0	218.0	1081.0	1081.0	3.5
4	4.286	180.0	816.0	774.0	0.8	360.0	2318.0	2318.0	2.6

Copper Water Tube, Type L

½	.545	2.9	1.0	—	8.2	5.8	2.5	—	29.0
¾	.785	6.0	2.5	—	5.2	12.0	7.3	—	18.7
1	1.025	10.3	5.5	—	3.9	20.6	22.5	7.0	13.7
1¼	1.265	15.7	11.5	5.0	3.0	31.4	58.0	15.5	10.7
1½	1.505	22.8	28.5	8.0	2.5	45.6	109.0	38.0	8.7
2	1.935	38.6	82.0	26.0	1.8	77.2	261.0	138.0	6.3
2½	2.465	59.5	172.0	75.0	1.4	119.0	474.0	356.0	4.9
3	2.945	85.0	300.0	178.0	1.1	170.0	750.0	692.0	4.0
4	3.905	149.0	636.0	544.0	0.8	298.0	1759.0	1759.0	2.8

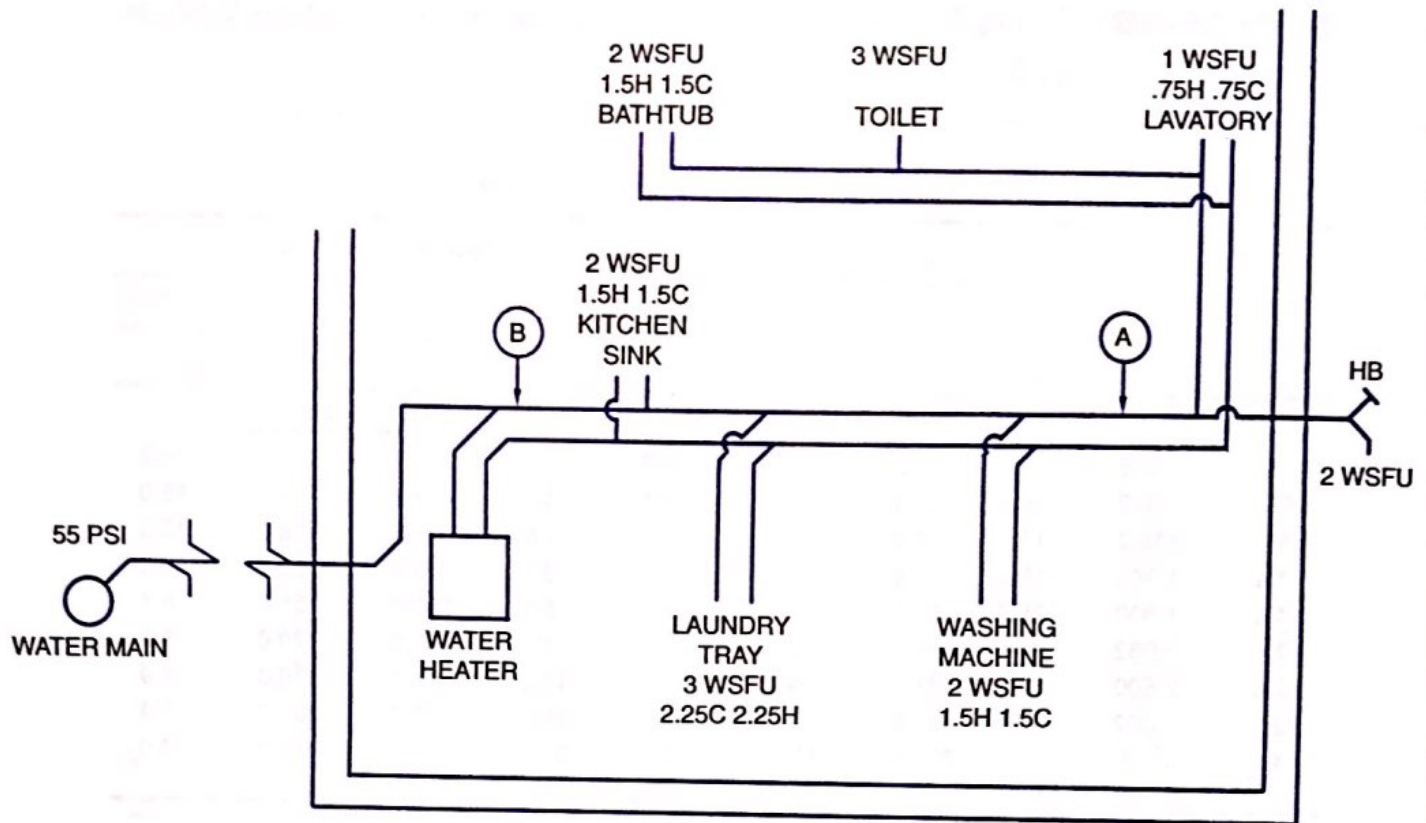


Figure 19-4 Sizing a water supply system includes assigning water supply fixture unit values to fixtures and equipment

WATER HEATER SIZING

In order to properly calculate the demand placed on a water heater, plumbers must know how the heater will be used. This chapter discusses tank-type water heaters, but the factors used to calculate hot water demand apply to tankless types as well.

Residential and commercial heaters have different demands and use different criteria. A residential heater is primarily used for bathing and cooking, whereas a commercial heater is used for multiple purposes; some nonresidential uses are listed in Table 19-6. Water heaters designed for these purposes have unique characteristics pertaining to their specific use.

The demand on a water heater is measured in gallons per hour (gph), and many fixtures are measured in gallons per minute (gpm). If the fixture can be used continuously, multiply the gpm by 60 (minutes) to determine the gph.

Manufacturers list the gph capabilities of every water heater, and plumbers use this information to select the correct heater. It is crucial that plumbers use the selection charts correctly; otherwise, they risk installing an undersized water heater that cannot provide adequate hot water. Installation of an oversized heater will provide (more than) a sufficient amount of hot water but will cost more to operate.

Determining Demand

The expected usage of a hot water system is called its system demand. Codebooks might indicate the average usage of known fixtures, or they might refer you to manufacturer information. Manufacturers indicate the capabilities of various water heater types and usually indicate the flow rates of fixtures and equipment in gpm.

Different showerheads have different flow rates. If the amount is not known, use the maximum flow rate listed in

Table 19-6 Nonresidential Water Heater Uses

Use	Notes
Coin-operated laundry, dry cleaner	Must know gallons per hour (gph) and multiply by total number of washing machines.
Locker rooms, prisons, campground	Multiply gallons per minute (gpm) of showerhead by 60 to determine gph.
Restaurant, cafeteria, or other food-preparation facilities	Must calculate all faucet and dishwasher gpm and gph; this use has higher temperature requirements.
Apartment or hotel not using individual heaters	Calculate each apartment or hotel room and multiply by number of units.
Car wash	Calculate gpm usage per wash, then multiply by 60 and by number of washes per day.

a codebook or standardized chart. The flow rate of a faucet varies by type; faucets that use an aerator, such as a lavatory faucet, have lower gpm flow rates than hose faucets.

If the water heater serves an existing facility, you can gauge the flow rate of each fixture by calculating the time it takes to fill a one-gallon container. Table 19-7 lists some common gph values used for various types of residential fixtures and activities. These values are not to be considered data to use for sizing a water heater on a job site; they simply provide examples of possible usage.

Determining Water Heater Size

This chapter focuses on tank-type water heaters. Once the usage of a system is known, the next step is to determine the btu rating of a heater to supply adequate amounts of hot water. The btu rating of a water heater indicates its capability to heat water to a certain temperature based on

Table 19-7 Examples of Average Residential Hot Water Usage

Use	Gallons Per Hour
Shower	20
Bathtub	20
Hand and face washing	4
Washing dishes by hand	4
Residential dishwasher	14
Hair washing	4
Preparing food	4
Washing clothes by hand	26
Washing machine	32

the incoming water temperature. The temperature rise (TR) refers to the difference between the incoming and outgoing water temperatures. When working with electric water heaters, manufacturers usually list the kilowatt (kw) rating and not the btu rating. As previously discussed in Section 4, the conversion from kw to btu is obtained by multiplying kw by 3,412. Once the TR and the gph are known, a manufacturer's catalog can be used.

Some sizing methods used within the plumbing industry recommend using the first-hour values listed in the manufacturer's catalog, but that could result in undersizing the water heater. The first-hour gph values apply only to a water heater that has no flow; the values describe the "cold start-up" process of heating the cool water within a tank. However, when hot water flows from the water heater, an equal amount of cold water enters, cooling the already heated water in a tank and creating a blended portion of stored water. Using the TR and calculating the actual demand method is more accurate and provides the gph required for adequate hot water based on specific usage.

Table 19-8 provides an example of a manufacturer's catalog sizing chart. Notice that the first-hour values are

larger than the 100° TR values, and the values listed for lower TR increase as the TR decreases. If the first-hour column were used, the incoming cold water would not be considered. Notice that the higher btu rating results in more gph of hot water produced. Some local health agencies that regulate restaurants do not allow anything but 100° TR to be used when sizing a water heater. Be sure to investigate local regulations before you size any water heater. Actual sizing charts include other information, such as tank capacity, and many of the same tank sizes are offered with various btu ratings.

Example:

Figure 19-5 illustrates a hot water piping system that serves several fixtures. Using the indicated gph for each fixture, calculate the total gph to select the correct water heater.

1. Calculate gph of the entire system.
2. Using the 100° TR column in Table 19-8, select the model number of the heater that can serve the demand.
3. The correct selection is model 789.

Table 19-8 Water Heater Sizing Chart Example

Model	btu	Gallons Per Hour			
		First Hour	100° TR	80° TR	60° TR
123	50,000	75	55	65	95
456	75,000	100	70	90	120
789	100,000	120	100	110	140
1011	150,000	160	120	140	200

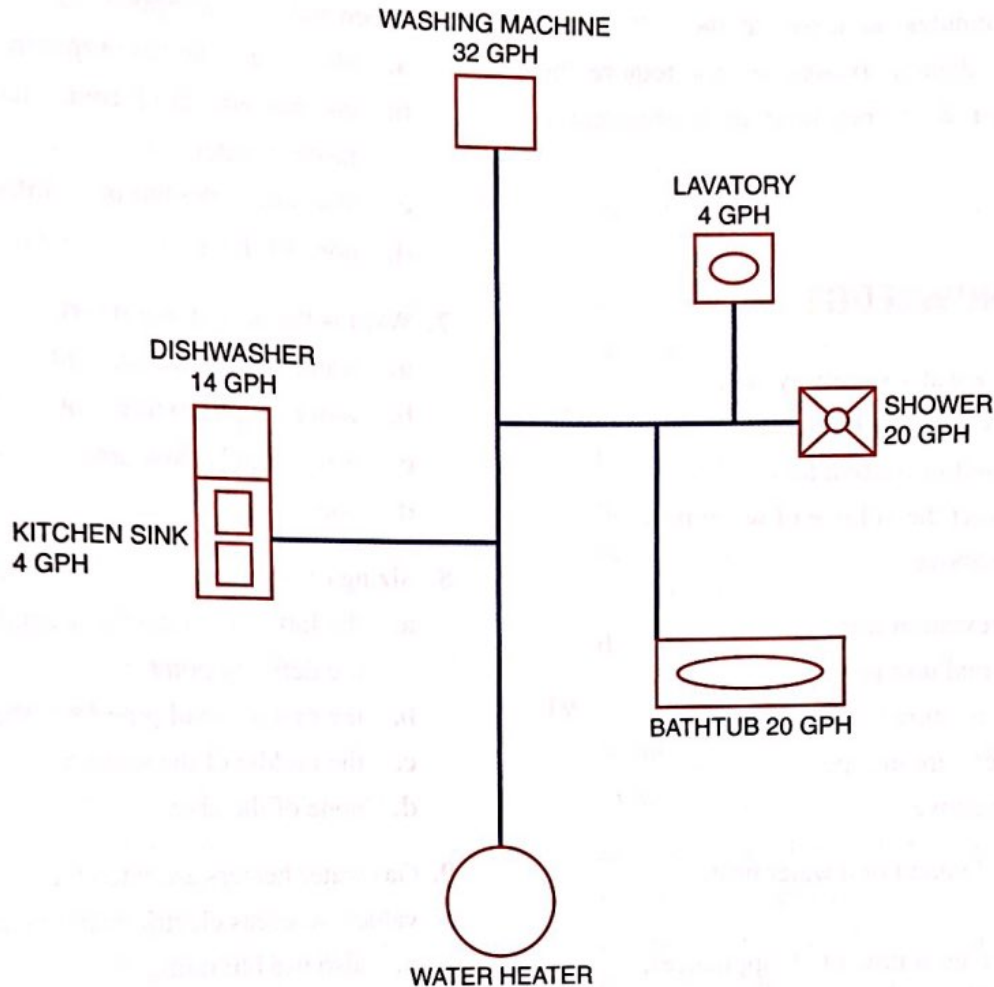


Figure 19–5 Plan view of a hot water piping system and fixtures

SUMMARY

To size a piping system correctly, a plumber must consider relevant codes and the specific appliances, fixtures, and equipment being served. The demands of each fixture are added together to arrive at the total demand of a system. Pressures available and drops in pressure are used to calculate the volume of water or gas that is supplied by a certain pipe size.

Gas supply is measured in cubic feet, and water supply is measured in gallons. The process of sizing a water heater also takes into account the total demand placed on a system.

Water heaters are sized based on the gallons per hour that a specific water heater can produce. Selection of a water heater is based on manufacturer information, using sizing charts found in the manufacturer's catalog. Gas water heaters use btu ratings, and electric water heaters use kilowatt ratings.

Water heaters are not always used for the same purpose; thus, codebooks might include common fixtures and their assigned values. If no data are available to indicate the gallons of water required for specific fixtures, a standardized chart can be used or you can gauge the flow rate of each fixture by calculating the time it takes to fill a one-gallon container. If the gallons per minute are known, multiply